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Research Plan for Study of Biological and Ecological Effects of the Solar Power Satellite Transmission System

Bernard D. Newsom

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RESEARCH PLAN FOR STUDY OF BIOLOGICAL AND ECOLOGICAL EFFECTS

OF THE SOLAR POWER SATELLITE TRANSMISSION SYSTEM

By Bernard D. Newsom

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BERNARD D. NEWSOM

SUMMARY

In a study of critical factors necessary to judge the feasibility of a Solar Power Satellite (SPS), it became evident that a dearth of information existed on the effect that microwaves, used to transmit power for the system, might have on man, plants, and animals of a lower order than man. Information to fill this void is required so that a decision concerning commitment to further SPS feasibility studies can be made. As a first step to develop the required information, the National Aeronautics and Space Administration (NASA) sponsored the preparation of a research plan for study of biological and ecological effects of SPS microwave radiation. A planning study was started on July 1, 1976, under NASA Research and Technology Objectives and Plans (RTOP) 776-13-71. The NASA sponsored research plan is reported herein. This plan was developed incorporating a programmatic approach to assure accomplishing the goal established and to provide visibility into progress of the research for management purposes. The Research Plan has considerable flexibility and can be funded at several levels to develop each area to the depth desired. An abbreviated version of the plan, at an annual funding level of $700,000 for a three year period is presented in the Appendix.

SYMBOLS AND ABBREVIATIONS

CW	continuous wave
GHz	Gigahertz
MHz	Megahertz
W	Watt
mW	milliwatt
μW	microwatt
λ	frequency
$\vec{E}$	direction of microwave electric field
$\vec{H}$	direction of microwave magnetic field
$\vec{K}$	direction of microwave propagation
ELF	extremely low frequency
UHV	ultra high voltage
dB	decibel
OEP	Office of Energy Programs, NASA
DOE	Department of Energy
NBS	National Bureau of Standards
EBF	Ecosystem Balance Facility
ODR	Oxygen Diffusion Rate
g	grams
R&D	Research and Development

I. INTRODUCTION

ACKNOWLEDGMENTS

The Research Plan presented is that defined by a consortium of Principal Investigators and their co-workers, in accordance with NASA Research and Technology Objectives and Plans (RTOP) 776-13-71 dated 1 July, 1976. Each Principal Investigator was awarded a NASA contract to produce the information presented in sections three through ten. Reports were submitted by each consortium Principal Investigator. The author has taken considerable liberty with some of these reports in order to achieve the consistency desired, and to balance the length of the sections. The Principal Investigators to whom NASA contracts were awarded are:

Section III. Prof. Om P. Gandhi, University of Utah

Section IV. Prof. Arthur W. Guy, University of Washington

Section V. Prof. H. Clarke Nielson, University of Utah

Section VI. Prof. Orlando Cuellar, University of Utah

Section VII. Prof. James R. Burleigh, California State University at Chico

Section VIII. Prof. Norman E. Gary, University of California at Davis

Section IX. Prof. Calvin H. Ward, Rice University

Section X. Dr. David C. L. Jones, Stanford Research Institute

It is the work and information supplied through these people that has composed this Research Plan and the reader is referred to each of their final reports for the complete text. Report titles are indicated in the respective sections. Copies of the reports are available from the Ames Research Center.

BACKGROUND

The concept to employ orbiting Satellite Power Systems in order to collect and convert energy in space for use on earth was proposed by Dr. Peter Glaser of Arthur D. Little, Inc. in 1968. Since then, a number of variations of the concept have

been proposed. These approaches have been promulgated as solutions to the energy problem without the contamination encountered with power production using fossil fuels or the possible radiological problems that develop through the use of nuclear reactors. All presently proposed methods for the production of power in space have in common the transport of very large amounts of energy by microwave from space to earth. The environmental impact from this transmission received over many square miles appears to be far less than other solutions to the energy problem but many aspects have not been researched in depth nor has the technology been fully tested. The most prominent of these areas, requiring additional knowledge before the environmental impact can be assessed, is the Biological/Ecological effects of microwave illumination over very large areas where flora and fauna are subjected to continuous exposures throughout their life-cycles for many generations.

CRITICALITY

In the United States, acceptable exposures to microwaves for long periods of time has been set at 10 milliwatts per square centimeter (mW/cm^2); acceptable standards within the USSR are set much lower and eight-hour industrial exposures are limited to 0.01 mW/cm^2. Considerable controversy exists about the validity of the criteria used in Russia to limit exposures to such low doses. In the United States, the acceptable field strength is based on the level at which no build-up in tissue temperature occurs, and it has been generally accepted that microwave damage to biological tissues is caused by a temperature effect; if the organism involved can remove the heat at a sufficient rate to prevent an increase in temperature, the field flux is considered to be acceptable. The Russians, on the other hand, believe that there are non-thermal biological effects produced, particularly those associated with the nervous system. It is their belief that impulses can be produced within nervous tissue through increased molecular activity and that these effects can be observed as behavioral changes.

During the last twenty years, eastern European scientists have built a body of microwave literature that has resulted in an increased concern in that part of the world about a possible health hazard related to long-term, low-level exposures to microwaves. In the United States, the acceptable dose of 10 mW/cm^2 has no factor included in it for the accumulation of effect with time. Soviet safety standards for microwave workers are stricter than the generally accepted voluntary U. S. standards, and "microwave sickness" is a recognized occupational disease which includes symptoms ranging from increased irritability to cardiovascular effects. Most of the studies upon which U. S.

acceptable dose standards are based, originated in the Department of Defense. The Defense Department set up a Tri-Service group to study the matter in 1956 and four years later recommended the standard of 10 mW/cm^2. That conclusion was reaffirmed in 1973 by the American National Standards Institute, yet, it has been pointed out that the Tri-Service group fixed that standard on the basis of experiments which mainly involved exposure to emissions of over 100 mW/cm^2. It is at 100 mW/cm^2 that the "thermal threshold" exists, because it is approximately that point where living tissue begins to accumulate heat. It is below 10 mW/cm^2 that controversy exists, and even though the data base is inadequate, the limit remains at 10 mW/cm^2, because nothing indicates that there is a frank hazard below that level.

Outside of the restricted receiving antenna zone on the ground, the predicted microwave radiation intensities decrease to 0.01 mW/cm^2 and lower. However, precise knowledge of local microwave intensities and the associated effects far from the rectenna site will require information not now available about orbiting satellite power systems and the environmental impact of such radiation. There is considerable lack of understanding concerning the effects of microwave radiation on living organisms and how to measure the absorbed dose. A great amount of work is required before meaningful, incident microwave exposure levels can be set. Although there is some data available on the effects of acute exposures of man and some animals, there is insufficient data available on chronic exposures to animals or to large land areas; particularly lacking is the data concerning effects on plants or soil.

Should the satellite power concept prove economically and technically feasible and become a Space program, it would be an effort many times larger than the Apollo Program. The public must possess evidence that ecological impacts have been studied, and that system plans are based on a firm understanding of the situation. Although progress in biological microwave research has been very slow, more information is required soon, to complement and supplement the engineering development.

THE SOLAR POWER SATELLITE (SPS)

Long term solutions to the power problem must rely upon renewable or non-depletable energy sources. Such sources include nuclear breeder reactors, nuclear fission, and solar energy. It appears probable that most all available sources for energy will be developed during the next century, and it can also be anticipated that there will be a continual rise in the costs of such power. Such increases in cost make techniques

which are not now economical, quite feasible for development as an energy supply at the time when their costs are competitive with other sources of energy. Solar power plants on earth are currently undergoing development and such development of terrestrial systems are advancing the technologies needed for the collection of solar energy in space. Solar power plants on earth are highly affected by climatic conditions and their location in latitude. Solar collectors in space located in geosynchronous orbit 35,786 kilometers (km) above the equator would absorb six times the energy of a terrestrial system at maximum efficiency and up to fifteen times more than such stations located at latitudes within the United States.

A fleet of such systems would be able to supply from ten to thirty percent or more of the total electric energy needs predicted for the end of the current century and the first part of the next. Engineering trade-off studies have concluded that 5-10 Gigawatt (GW), five-to-ten billion watt, systems are suitable from economic and microwave energy transmission viewpoints. In order to collect this amount of solar energy, areas ranging from 60 to 180 km^2 may be required. The size depends upon the conversion system used to produce electric power from the solar energy, and the possible concentration of sunlight with the method. In any event, these solar collectors in space are comparable in square area to the size of a large city such as San Francisco, and each would weigh from fifty to one hundred thousand tons. Because a great deal of the cost of Solar Power Satellite energy is the investment into the development of such a system, the more systems flown, the more cost-effective it becomes. Some scenarios call for as many as one hundred of such satellites eventually being in orbit.

The power transmission system which sends the collected energy to earth is common for all conversion systems. As now envisioned, the satellites would transmit power to earth by means of microwaves, employing one or two antennas, each having a capability to deliver 5 GW of net power (at the bus bar) on the ground. The receiving antenna (rectenna) on the ground has a corresponding capability to collect and convert the 5 GW of net power. As now envisioned, the rectenna would convert the microwave energy to direct current electricity. The size of the rectenna can vary, depending upon the characteristics of the transmitting array, geographic location, fraction of beam interception, the pointing accuracy of the antenna, and random phase error, but it will be an elliptical field of approximately 8.5 by 11 km. The continuous wave (CW) microwave energy is transmitted at 2.45 gigahertz (GHz) as this is optimum frequency to minimize energy loss from water absorption and upper atmospheric interactions. Upper atmospheric interactions may limit the energy density of the beam to approximately 23 mW/cm^2 at

beam center; the rectenna size is chosen so that the energy density decreases to 1 mW/cm^2 at the rectenna edge. It is anticipated that there will be a restricted zone around the rectenna system, the width of which is dependent upon the permissible dose that still needs to be established for general population exposures. Recent design studies indicate that if 0.1 mW/cm^2 microwave exposure intensity is found to be acceptable, then a 1.3 km wide band around the rectenna would be adequate. If one hundred satellites were in orbit, there could be some one hundred to two hundred rectenna receiving areas within the United States. Another factor within the SPS system design concept pertinent to the Biological and Ecological impact is that the system is engineered to have a lifetime of thirty years, and would pay back the energy used for construction in approximately one to two years. A great many engineering studies and system analyses have been performed on the Solar Power Satellite system and for further details, the reader is referred to four NASA publications:

1. Feasibility Study of a Satellite Power Station, by Peter E. Glaser, Owen E. Maynard, John Mackovciak, Jr., and Eugene L. Ralph, NASA CR-2357, February, 1974.

2. Initial Technical, Environmental and Economic Evaluation of Space Solar Power Concepts, JSC-11568, Lyndon B. Johnson Space Center, August 31, 1976.

3. Satellite Power System Engineering and Economic Analysis, NASA TM X-73344, George C. Marshall Space Flight Center, November, 1976.

4. Solar Power Satellite Concept Evaluation - Activities Report, July 1976 to June 1977, JSC-12973, July, 1977.

Objectives of the Research Plan. - The satellite power concept proposes that solar panel arrays with lifetimes of thirty years be placed in geosynchronous orbit to collect solar power for subsequent relay to ground collecting stations by microwave. The biological effects of this type of continuous long-term radiation, requires in-depth examination by laboratory studies and field-testing procedures. Initial microwave transmission tests have been conducted by the Lewis Research Center and the Jet Propulsion Laboratory. During such engineering development tests, preliminary biological tests can also be performed. Agencies outside of NASA are currently funding general mechanism studies and dosimetry development; such work

could be accelerated in existing facilities with increased support. The problems imposed by continuous (chronic) microwave emission on life-cycles of plants, microorganisms and animals is however, unique as proposed by the NASA Research Plan. A study also needs to be performed to determine the field-test facility required for realistic simulation of the area about the rectenna system. A planning stage can then be initiated for site construction, culminating in a Microwave Biological Research Laboratory. Participation by many agencies in the research to be performed is anticipated, which includes the Departments of Forestry, Agriculture, and Health, Education and Welfare. Many aspects of the problems to be studied will also be of direct concern to the Department of Defense as it pertains to their radar facilities.

The means of minimizing effects to the human populations around a rectenna system is to border that system with a large restricted area, not accessible to the general population, and hence, minimize exposure of a population. Such a conservative approach, however, would not protect birds flying through the area, nor would it prevent some of the secondary effects possibly caused by nesting birds, attracted to the heat of the area, increased breeding rates of insects, and changed life-cycles of soil microorganisms. It is very possible that beneficial effects could result in some biological organisms, either directly or indirectly, and in humid areas, it is possible that increased precipitation arising from local convective thermal currents could occur. These all could be expected to evoke changes in the flora and fauna in the immediate area. The rectenna area itself encompasses a sizable amount of land, and hence, it poses an ecological impact by land use alone. In many areas this would be inconsequential; however, in others, it may be efficient to have the receiving sites in areas of high land value close to the user site. To minimize the effect of land use, it would be desirable to use both the restricted area around the rectenna system, and possibly the area below the rectenna system, for some productive purpose. Such purposes range from poultry-husbandry to breeding of large farm animals, and could also include vegetative crops similar to the truck-farming enterprises. The peripheral areas may also be used for grain crops or possibly for tree-farming areas. Such endeavors as tree-farming would fit well into the thirty year proposed life-time of the operating system. In order to exploit such potentials, however, considerable information is required on the effect of microwaves on plants and trees, and that is non-existent at the present time. Birds, both those used for poultry purposes, and also for migrating flocks, that may be attracted to or passing through the area also need to be studied to understand their tolerances and the effects that such an environment would have on their life-cycles. Because of the peculiarities

of the absorbed dose and dosimetry of microwaves, it is important to study dose accumulation effects in large farm animals such as cows, pigs, and sheep to understand the limits of biological tolerance that differ from humans because of shape, gross size, and orientation of body axis within the field. The increased soil temperatures and possible changes in humidity could be either detrimental or beneficial to insect populations, and such receiving areas could become breeding grounds for certain insect populations.

When basic information has been acquired about these areas of information within the laboratory, it will be important to empirically test the proposed acceptable doses, both direct and indirect effects, in the field.

Present concepts for exposure limits do not include the concept of accumulative damage, because of the generally accepted heat accumulation concept, within the United States. Plants and many biological specimens which are cold-blooded may react quite differently than warm-blooded animals and dosimetry concepts will be required to establish such exposure limits, in terms of an absorbed dose expression as a function of both density and time. Should additional evidence be accumulated that indicates existence of non-thermal biological effects or damage, it will be necessary for the proper agency to set dose limits, not only for the individual, but also for a community at large; such dose limits might be quite different from that which would be acceptable as periodic exposures for workers, whose dose exposures can be well controlled and precisely measured. The consequences associated with accidental exposures also require definition, not only for treatment purposes, but for legal responsibilities, as it is this area that may well define operational standards. Such limits and legal requirements will have impacts upon the maintenance of the operating system both on earth and in orbit, for they will dictate rotation times for crews and define logistic requirements.

Recommended Approach. - Judging from the research on biological effects of microwaves in the past years, the time required for developing the desired information is greater than that available, before system design and prototype testing is scheduled to occur. Areas of biological research, therefore, need to be judiciously chosen for accelerated study. Appropriate study areas already developed in existing laboratories can, in some cases, be beneficially supported by increased funding. The preliminary power transmission studies at Goldstone, by Lewis Research Center and the Jet Propulsion Laboratory could be increased to include some aspects of a biological program. In parallel with that effort, it is proposed that a study be initiated to define the requirements for advanced research and how

those requirements can be incorporated into a Biological Microwave Research Facility. Such a facility would be restricted to the study of those SPS specific areas that have not been under investigation by other agencies; the interest by other agencies has been mainly directed toward the microwave effects and tolerance limits to be imposed on human beings. It may also be necessary to do me specific human research work, for defining microwave toler ce exposure limits that are peculiar to the SPS concept, which are not being studied at other agency laboratories or through their sponsorship.

It is necessary to initiate as soon as possible, the study of direct and indirect effects of the microwave illumination on the life-cycle of representative flora and fauna in a simulated environment, at the specific frequency chosen for the microwave transmission, and at the densities anticipated for transmission by the SPS system. The studies should include proper orientation of the microwaves to establish SPS transmission effects. Associated with such studies, dosimetry techniques must be developed which include some expression of accrued long-term exposure.

Under some circumstances, it is conceivable that rectenna sites would be over water; changes could result in altered plankton growth in ocean areas, having cascade effects throughout the aquarian environment. Such effects need not necessarily be detrimental, and it could be possible that placing a rectenna system over water would increase fish population. The Research Plan presented, however, has considered only terrestrial site selections.

II. RESEARCH PLAN STRUCTURE AND INTEGRATION

History and Background. - In 1975, the NASA Headquarters Office of Energy Programs, then under the direction of Astronaut Harrison H. Schmitt, Ph.D., assembled a Solar Power Satellite study team to examine a concept that was presented by Dr. Peter E. Glaser in 1968, that involved placing large solar power satellites in geosynchronous orbit and beaming microwave energy down to collection stations on earth. This study team was composed of senior NASA members, representing each of the Research Centers. The task of the group was to examine the concept in minute detail and to list those areas that were critical to the judgment of feasibility for which the necessary state of the art and knowledge were not currently available. These critical areas were then studied to determine what investigations would be necessary to derive the information required and to estimate the magnitude of the task to acquire it. The Office of Energy Programs, at that time, wished to be in a position by 1980, to either reject the concept or to commit themselves to an expansion of the effort to acquire a base-line conceptual design.

Critical areas were found to exist in all parts of the system, but most of these were technical areas, where the problems were principally that of development of existing technology to a higher state of perfection, or creating new design concepts with knowledge that is now available. The environmental portion of the study, however, clearly exposed a lack of critical knowledge in many of the physical areas pertaining to evaluation of the microwave hazard, and a complete dearth of biological information that could be considered as accepted and factual in the ecological area. This area appeared to be of great importance, because of the emotional aspects that erroneous concepts could generate, and that could be generated by exploitation of the fears possible to engender, due to the total lack of substantiated knowledge on the subject. The small amount of information that is available has been derived mainly for assessing the microwave hazards to man and the only microwave effect information available on animals is that derived from the use of animal surrogates for the study of the microwave hazard to man.

Existing information does not indicate, in any way, that the power densities of the CW 2.45 GHz transmission would be deleterious to any part of the environment or hazardous in any way to either the general population surrounding the site or to employees within the site. The microwave exposure of employees within the site cannot even be considered a critical point, because such exposures will be monitored and there are many ways available to provide protection to such individuals.

Critical information about the microwave effects on the environment was lacking for all the major phylum, and without such knowledge, any attempt to assess the problem could be made to appear highly suspect. Organization of a Research Plan to generate the necessary information, then required participation by members from all aspects of terrestrial biology. It cannot be assumed that all effects, if they existed, would be negative. A positive effect to a single species could also upset an ecological balance. A positive effect, however, could also offer the possibilities of exploiting the restricted area around the rectenna site and the area beneath it for some form of agriculture.

It was felt by the Office of Energy Programs that information on the Biological and Ecological systems would most definitely be required for further commitment to the concept, and the task of structuring a plan to provide such a large amount of data in a period of three years would require a plan that could be closely managed. To provide the visibility desired, it appeared a programmatic approach with scheduled milestones was required. A concept was proposed for the development of a phased program that would allow periodic examination of new knowledge prior to further SPS commitment.

Approach. - The phased approach consisted first -- of a six month period in which a research plan was to be developed and this period was called the Definition Phase. Phase A was then the three year period in which that plan would be followed to develop a maximum amount of information concerning the unknown Biological and Ecological effects of microwaves, pertinent to the Space Power Satellite Rectenna Receiving Area. If the information developed by the time of the 1980 decision, concerning further commitment in all of the critical areas being studied, indicated the concept as still being feasible, then studies would proceed into Phase B, of an undefined period of time in which mechanisms would be studied. Phase A was restricted to Effects Studies of microwaves with physical characteristics of the SPS, so they could be performed on schedule and so a maximum amount of information pertinent to the decision could be produced. Mechanism studies by nature are heuristic and open-ended, making them nearly impossible to schedule or direct.

Commitment to a Phase C would also be dependent upon the decision that the concept was feasible, at the time when Phase B was ended. During Phase C, species interactions would be looked at and emphasis could then be placed upon the ecological studies where the effects of the microwaves are looked at within

an entire community rather than individuals. If funding and facility availability permitted, Phase C could be conducted simultaneously with Phase B, as it is a continuation of the effect studies and does not depend upon results of Phase B. Phase D at this time is only a loosely defined research period, where it is anticipated that prototype hardware would be under test and operational procedures would be under development. Such operational procedures affecting man or possibly the environment would be examined at that time under realistic situations.

Organization of the Plan. - Eight categories were defined into which all of the required information about microwave effects appeared to fall. These categories were:

1. Microwave Energy Absorption

2. Chronic Low Dose Exposure

3. Birds

4. Heterotherms

5. Insects

6. Mycology

7. Plants

8. Dosimeter and Facility Development

The three year research plan was to be structured so the program could be evaluated and reviewed on a continual basis by management and it would be goal oriented. It was felt that recognized researchers in University Laboratories, rather than those in private support-dependent institutes associated with the goals of NASA would be required to work the program, if the information to be generated was to be accepted by the general public. The difficulty with such an approach is that researchers in the academic laboratories are less amenable to the regimentation techniques used in development laboratories, where specific information goals are being sought, and the work is done to a schedule that is in concert with the many other systems being worked simultaneously.

The foundations on which the plan was to be organized were the categories--these were reviewed and justified. The microwave energy absorption is an area of considerable importance because at the current time, there is no agreed upon method of describing the energy absorbed from microwaves, means to measure it, nor ways to anticipate its effects in terms of biological consequence. The means for measuring absorbed energy within the

laboratory are totally inadequate for use under field conditions. The general practice of describing an encounter with the microwave environment, in terms of the incident illumination, means very little in terms of the absorbed energy under actual field conditions because of the many factors of alignment, reflection, grounding, and resonance.

Although there are numerous inferences to non-thermal bioeffects of microwaves, no such repeatable effects had been statistically shown to exist in the United States; it is in the area of chronic low dose exposure that such effects are most often purported, and it is the concern about the possibility that these effects exist, that have set design guidelines for general population exposures below 1 $mWcm^2$, and could if not countered with acceptable data, drive it below that. Though possibly warranted, such stringent guidelines for design could have substantial impacts on cost and feasibility.

Both the dose absorption studies and the chronic low dose exposures make extensive use of small mammals, and the goal is to extend some of those studies to larger mammals. Other animals, however, have not been studied--these include the birds, reptiles and amphibians. Birds are a particularly vulnerable fauna since they have free access to the receiving site and could possibly seek the area as a protective one for nesting. Other problems could result from the beam, such as disruption of established migratory flyways, and under some circumstances, increased body temperatures that could interfere with flight capability.

The reptiles are a convenient species to study the effects of microwaves on a cold-blooded animal, or heterotherm. These animals usually have a small domain; they are heat seekers and play an important role in insect control. Insects also have free access to the area and avoidance or attraction could each have consequences in maintaining the receiving site, in as much as they are ecologically important as a food substance to the birds, and some species are necessary to crop pollinization. Mycology, the study of the lower order of plants, molds and fungi, plays an important role in general ecological balance. It can be an instigator of higher order plant disease and the fungi are also responsible for the decomposition of dead cellulose matter. The fungi of interest should not be affected by microwaves at a frequency of CW 2.45 GHz, particularly at such low energies as encountered at the rectenna site. This is an area where it is important to generate sufficient data to assure general acceptance for the lack of an effect.

Plants can be considered from two aspects--one, the importance it has to the ecological question for acceptance into an

area and two, for many types of agriculture or tree-farming that might be used to reduce the land impact of the system. Throughout the growth cycle of the plant, there are several stages where resonance would have peak effects--the plants are grounded, and they are aligned for maximum energy absorption in the E field. It too, is an area where little if any meaningful research has been performed.

The dosimeter and facility development category is one included because of the long lead times required for these items to be produced. As mentioned previously, subject and personal dosimetry is extremely rudimentary for microwaves, and concepts to structure the problem need to be developed, as well as the hardware eminating from those concepts. Phase A research is to be done in existing laboratories on essentially isolated subjects, but more advanced work into the mechanisms and more important, the ecological studies necessary to understand what will happen within the rectenna site and around it, will also call for rather extensive facilities,that require long lead times.

Following acceptance of the Categories, recognized authorities within academic institutions were acquired to plan the research in their areas of expertise. The first step was to prepare a prioritized list of questions in each Category, which the authorities felt were critical to the NASA/DOE commitment to further funding of feasibility studies on the SPS. The priorities assigned to each question were justified, and then for each question, a series of experimental protocols were developed, which the authority felt were necessary, to derive the information to answer the question. The protocols were brief and prepared with only sufficient detail, so the time period to complete the particular protocol could be estimated along with the man years of effort required during that period of time and the cost to support that research. Also included were the facilities needed for each protocol. The third step was to sequence the experimental protocols in such a way that they could be completed within the allotted three year period. These sequences, or planning charts, were prepared in a PERT type form, showing the period in which the experiment would be performed, when it would be finished, and the cost and man years required. Each question then stood alone as a PERT chart and prepared in a way which could be critiqued and handled as a single request for proposal on competitive bidding. In the preparation of this plan, each authority was required to make assumptions for which there was absolutely no supportive evidence. Where such situations existed, pilot experiments were done in the laboratory, not for the purpose of answering the question, but for confirmirg their assumptions pertaining to equipment, approach, etc., involved in the plan.

The research plan then consists of Categories, Critical Questions, Protocols, and Required Facilities, all shown in a planning chart which provides the essential information needed for a more sophisticated PERT network. From these charts, milestones and schedules can be easily derived to provide the administrative visibility requested and the flexibility to manage parts of the program. A numerical scheme was prepared to identify the protocol from the chart and to identify facility requirements. Each Protocol has a four digit designation: the first digit refers to the Category; the second digit--the Priority of the Question; the third--the Experiment Sequence, and the fourth--the Facility Requirement. An example of the system is shown in Figure 1, using a hypothetical Category, 0.0.0.0. The First Priority Question would then become 0.1.0.0, the first Task or Experiment would then be 0.1.1.0, and the Facilities Required to support that task are 0.1.1.1, 0.1.1.2, and 0.1.1.3. Tasks 2 and 3 use the same facilities as required for the first task; Task 4 requires an additional facility and is designated as 0.1.4.1. Each facility also shows the approximate Time to Develop the Facility, the Man Power needed during that period, and the Dollar Cost.

There was no indication of what funding might be, but by prioritizing the questions, it provides management the flexibility to fund the plan to various depths in various Categories. In many cases, the sequence of experiments can be altered, if necessary, to do some experiments within a question, in parallel that are now presented in series, in order to adjust to budget availability. The research is in a form that allows the programmatic control and visibility desired. The experimental protocols used to develop the planning charts for each question, contain the information necessary to generate a contract. Table 1 is the outline to which each of the protocols was structured, and it provides the information usually listed as one task in a "Request for Proposal" work statement.

BIO-ECO RESEARCH PLANNING AND NUMERICAL REFERENCE SCHEME

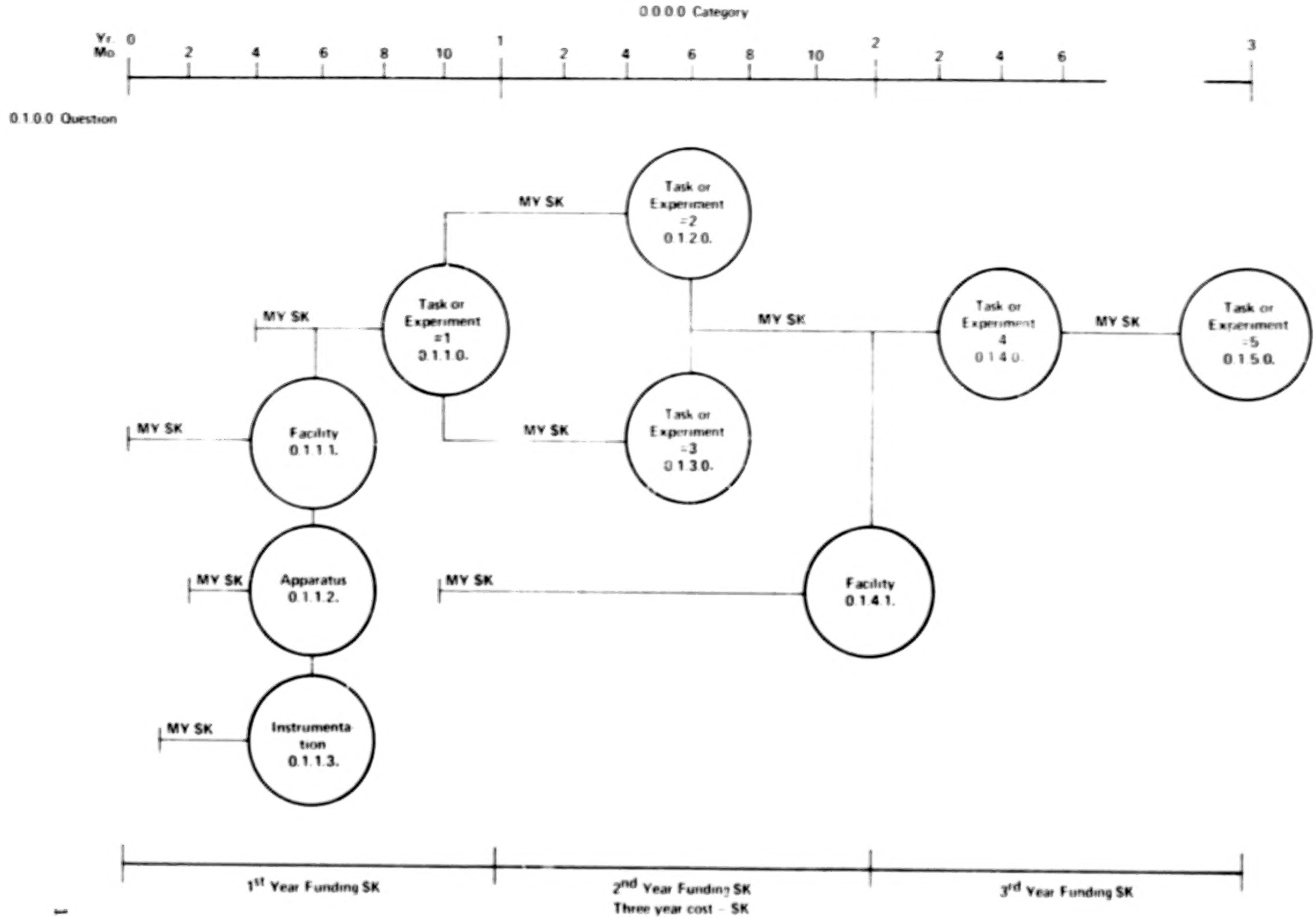

Figure 1

TABLE 1
PROTOCOL FORMAT

0.1.0.0 FIRST QUESTION IN CATEGORY?

PROTOCOL 0.1.1.0 FIRST EXPERIMENT TO ANSWER QUESTION

- HYPOTHESIS OR TASK:
- APPROACH:
- INFORMATION TO BE DERIVED:
- EXPERIMENT TIME:
  - MONTHS TO COMPLETE
  - MAN YEARS REQUIRED
- COST FOR RESEARCH:
- NEW FACILITIES REQUIRED:

	TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
0.1.1.1	FIRST FACILITY REQUIRED			
0.1.1.2	SECOND FACILITY REQUIRED			
0.1.1.3	THIRD FACILITY REQUIRED			

III. ABSORPTION OF CW 2.45 GHz MICROWAVE ENERGY IN MAN AND ANIMALS*

SIGNIFICANCE OF CATEGORY

This task pertains to determination of absorbed dose and its distribution in man and animals subjected to CW 2.45 GHz plane waves from proposed space power satellites. It is often said the research in the field of microwave biological effects without proper knowledge of dosimetry, is like working in drugs research without knowing the amount of drug administered the subject. That a prescribed field strength of 25 mW/cm^2 at a given frequency does not tell the whole story is best illustrated by an example from Schrot and Hawkins (1) work on times to lethality of rats and mice at several frequencies for different polarizations of incident waves. Mice oriented along the electric field ($\vec{E} \| \hat{L}$) convulsed in an average time of 9 minutes for an irradiation power density of 150 mW/cm^2 at 985 MHz, while similar animals oriented along the microwave magnetic field lived through an observation time of one hour without undue stress. For comparable convulsion times, field intensities differing by 30:1 or more, are not uncommon, and fairly small incident power densities may be considerably enhanced in their potency by the presence of reflecting surfaces (2), ground effects, and other animals (3) nearby.

From the foregoing, it is clear the the absorbed dose may vary drastically, depending on the species and the physical environment under which the radiation is incident on the experimental animals. A determination of the absorbed dose and its distribution is consequently important for research in microwave biological effects.

Before giving the list of critical questions in this area, it is appropriate to summarize the state of the knowledge in the field of microwave dosimetry. This is done in order to point out the many deficiencies in present knowledge of absorbed dose for man and animals. The critical questions itemized are to address these deficiencies.

*Abstracted from the Final Report for Ames Research Center, NASA Contract NAS2-9555 "2450 MHz Microwave Absorption in Large and Small Animals and Its Biobehavioral Effects on Birds and Reptiles", Om P. Gandhi, H. Clarke Nielson, James L. Lords, John A. D'Andrea, Orlando Cuellar, and Mark J. Hagmann, University of Utah, February 2, 1978

STATE OF THE KNOWLEDGE FOR ELECTROMAGNETIC

ABSORBED DOSE IN MAN AND ANIMALS

Free-Space Irradiation Condition. - The condition that has been studied the most, to date, is that of free-space irradiation of single animals. The whole-body absorption of electromagnetic waves by biological bodies is strongly dependent on the orientation of the electric field ($\vec{E}$) relative to the longest dimension (L) of the body. The highest rate (4) of energy deposition occurs for ($\vec{E}||\hat{L}$) orientation, for frequencies such that the major length is approximately 0.36 to 0.4 times the free-space wavelength (λ) of radiation. Peaks of whole-body absorption for the other two configurations (major length oriented along the direction of propagation ($\vec{k}||\hat{L}$) or along the vector of the magnetic field ($\vec{H}||\hat{L}$) have also been reported (5) for L/λ on the order of $L/4\pi b$, where $2\pi b$ is the weighted average circumference of the animals.

Using prolate spheroidal and ellipsoidal equivalents of biological bodies, theoretical calculations have recently been given in a dosimetry handbook (6) for frequencies up to and slightly beyond the resonant region for the aforementioned polarizations ($\vec{E}||\hat{L}$, $\vec{k}||\hat{L}$, and $\vec{H}||\hat{L}$). Numerical calculations for a realistic mode (7) of man have shown a finite structure to whole-body absorption at frequencies higher than the whole-body resonant frequency. Minor peaks in the supraresonance region are ascribed to maxima of energy deposition in the various body parts such as the arm and the head (3).

For the supraresonant region, the $\vec{E}||\hat{L}$ orientation has been studied most extensively. An average $1/f$ dependence of the whole-body absorbed dose is experimentally observed (2) to frequencies f on the order of $1.6\ S_{res}$ times the resonant frequency f_r, where S_{res} is the relative absorption cross section at the resonant frequency.

For the maximally absorbing (and most understood) $\vec{E}||\hat{L}$ orientation, the empirical equations for SAR have been developed for the supraresonant region, and these are:

Peak absorption or resonant frequency $f_r = 11.4/L_{cm}$ GHz (1)

for $f_r < f < (1.6\ S_{res})\ f_r$

	For man models	For animals
S_{res} =	$0.481 \sqrt{\frac{L^3_{cm}}{\text{weight in g}}}$	$0.765 \sqrt{\frac{L^3_{cm}}{\text{weight in g}}}$
SAR in mW/g for 1 $mWcm^2$ incident plane wave field	$\frac{5.45}{f_{GHz}} \frac{L_{cm}}{\text{weight in g}}$	$\frac{9.47}{f_{GHz}} \frac{L_{cm}}{\text{weight in g}}$

The above empirical equation for SAR has been checked against experimental results for several animal species that were illuminated at CW 2.45 GHz (planned SPS frequency). As may be seen from Table 2, the empirical values of SAR are in farily good agreement with experimental values for animals from 22 gm vole *microtus Montanus* to 2245 gm rabbit. The coefficients in the above empirical equations for man models are approximately 63 percent of the live animal coefficients. Further research is needed to resolve this difference. Also the results for the supraresonant regions for the other two configurations, $\vec{k} \| \hat{L}$ and $\vec{H} \| \hat{L}$, are not as well understood.

Electromagnetic Absorption for Man and Animals in the Presence of Nearby Ground and Reflecting Surfaces. - Only highly conducting (metallic sheet) ground and reflecting surfaces (2,8) of infinite extent have been studied to date. For a standing man model with feet in conductive contact with a perfect ground, there is a drastic alteration in SAR as a function of frequency. For $\vec{E} \| \hat{L}$ orientation the new resonant frequency is roughly one half that given Eq. (1). At this lower resonance frequency, the SAR is about twice that at peak absorption frequency for free-space irradiation.

Other orientations and/or finite conductivity ground effects on SAR have not been studied to date.

For highly conducting (metallic sheet) reflecting surfaces of flat- and 90°-corner types, enhancements (2) in SAR by factors as large as 27 have been observed for $\vec{E} \| \hat{L}$ orientation. Most of the work to date has concentrated on frequencies close to the resonance region. The observed enhancement factors are

TABLE 2

SAR IN MW/GM FOR $\vec{E} \parallel \hat{L}$ ORIENTATION

FREE SPACE EXPOSURE CONDITION

WEIGHT GM	LENGTH* CM	SAR IN MW/GM FOR 50 MW/CM^2 FIELDS		PERCENT ERROR
		FROM MEASUREMENTS	FROM EMPIRICAL EQUATION	
LONG EVANS RAT (*RATTUS NORWEGICUS*)				
355	21	11.72	11.43	+ 2.5
490	25	8.47	9.86	-14.1
499	26	9.41	10.07	- 6.5
506	26	9.41	9.92	- 5.1
508	25	8.47	9.51	-10.9
550	26	7.53	9.13	-17.5
500	--	9.48	--	--
RABBIT (*NEW ZEALAND WHITE*)				
2000	44	3.80	4.25	-10.6
2000	44	4.27	4.25	+ 0.5
2245	43	3.90	3.71	+ 5.1
VOLE (*MICROTUS MONTANUS*)				
24	9	68.61	72.48	- 5.3
22	8.5	72.94	74.67	- 2.3
23	8.5	70.40	71.43	- 1.4
DEER MOUSE (*PEROMYSCUS MANICULATUS*)				
29	8.5	58.9	56.63	+ 4.0
24	8	68.61	64.41	+ 6.5

*The length of the animals was measured from snout to posterior portion of animal body excluding the tail in anesthetized animals.

TABLE 2. - CONCLUDED

WEIGHT GM	LENGTH* CM	SAR IN MW/GM FOR 50 MW/CM^2 FIELDS	
		FROM MEASUREMENTS	FROM EMPIRICAL EQUATION
RING DOVE (*STREPTOPELIA RISORIA*)			
141.5	14	30.13	19.12
143.2	15.5	37.66	20.92
144	13	29.03	17.45
144	13	28.60	17.45
120.3	--	29.76	--
			EFFECTIVE LENGTH FROM EMPIRICAL EQUATION
WHIPTAIL LIZARD (*CNEMIDOPHORUS TIGRIS*)			
24	9.5 + 21 cm tail	124.55	15.46
23	9.5 + 9 cm tail	133.95	15.95
20.5	8.5 + 22 cm tail	124.77	13.26
18.8	9.5 + 10 cm tail	92.15	8.95

*The length of the animals was measured from snout to posterior portion of animal body excluding the tail in anesthetized animals.

explained (2) on the basis of antenna theory (9). Indeed, for incident plane waves for $\vec{E} \| L$ orientation, most of the observed results are as though the target acted like a pick-up half-wave dipole with reflecting surfaces in close vicinity.

Finite conductivity, finite size reflecting surfaces, and other orientations have not been considered to date. Also, the results for frequencies higher than about 8.5 times the resonant frequency (550 MHz for man) have not been obtained even for highly conducting reflectors.

Multianimal Effects (3). - It has been shown that for resonant biological bodies close to one another, the antenna theory may be used to predict the modification in SAR relative to free-space values. For two resonant targets separated by 0.65 to 0.7 λ, the highest SAR, 150 percent of the free-space value has been experimentally observed for anesthetized rats and models of man for $E \| L$ orientation for frontally (broadside) incident plane waves. For three animals in a row with an interanimal spacing of 0.65 λ, the central animal SAR about two times that for an isolated animal is observed.

The results are not available for subresonance and supra-resonance regions. Also other orientations, irregular spacings, and non-free space exposure conditions have not been considered to date. Enhanced SARs due to proximity to other targets may be of significance for birds on account of their perching patterns and for plants.

PRIORITIZED LIST OF QUESTIONS

1. WHAT IS THE SAR FOR MAN AND LARGE ANIMALS FOR CW 2.45 GHz FREE-SPACE IRRADIATION FOR DIFFERENT POLARIZATIONS?

In the absence of precise theoretical and experimental wor for man above 500 MHz, the energy deposition has been calculated from the quasi-optical approach (10,11), in which infinite plana or cylindrical models of man are assumed. A more rigorous theoretical model and experimental confirmation of the results are needed. Also, for animals where quasi-optical approach is erroneous, $\vec{k} \| \hat{L}$ and $\vec{H} \| \hat{L}$ orientations have not been studied to any significant degree.

2. WHAT IS MICROWAVE ENERGY ABSORPTION IN SMALL ANIMALS AT CW 2.45 GHz?

Pilot experiments for $\vec{E} \| \hat{L}$ orientation for two and three identical targets have shown an enhancement in SAR to 1.5-2.0 times the free-space value for interanimal spacing on the order of 0.65-0.7 λ. Relatively nothing is known about the change in SAR for other polarizations, non-resonant conditions, irregular spacings, and nonfree-space exposure conditions. A quantification of multianimal effects on SAR is needed to prescribe the absorbed dose for birds on account of their perching patterns and for laboratory experiments with multiple animals that are simultaneously exposed to microwave radiation.

As aforementioned, a significant enhancement in SAR may be cause in the presence of reflections from ground and other surfa . An 86 percent enhancement was found in SAR for whiptail lizards *Cnemidophorus tigris* due to reflections from a dry sand substrate during the pilot study. Enhancement factors as large as 4-5 may occur for wet soil conditions.

PLANNING CHARTS

1.1 MICROWAVE ENERGY ABSORPTION IN MAN AND LARGE ANIMALS

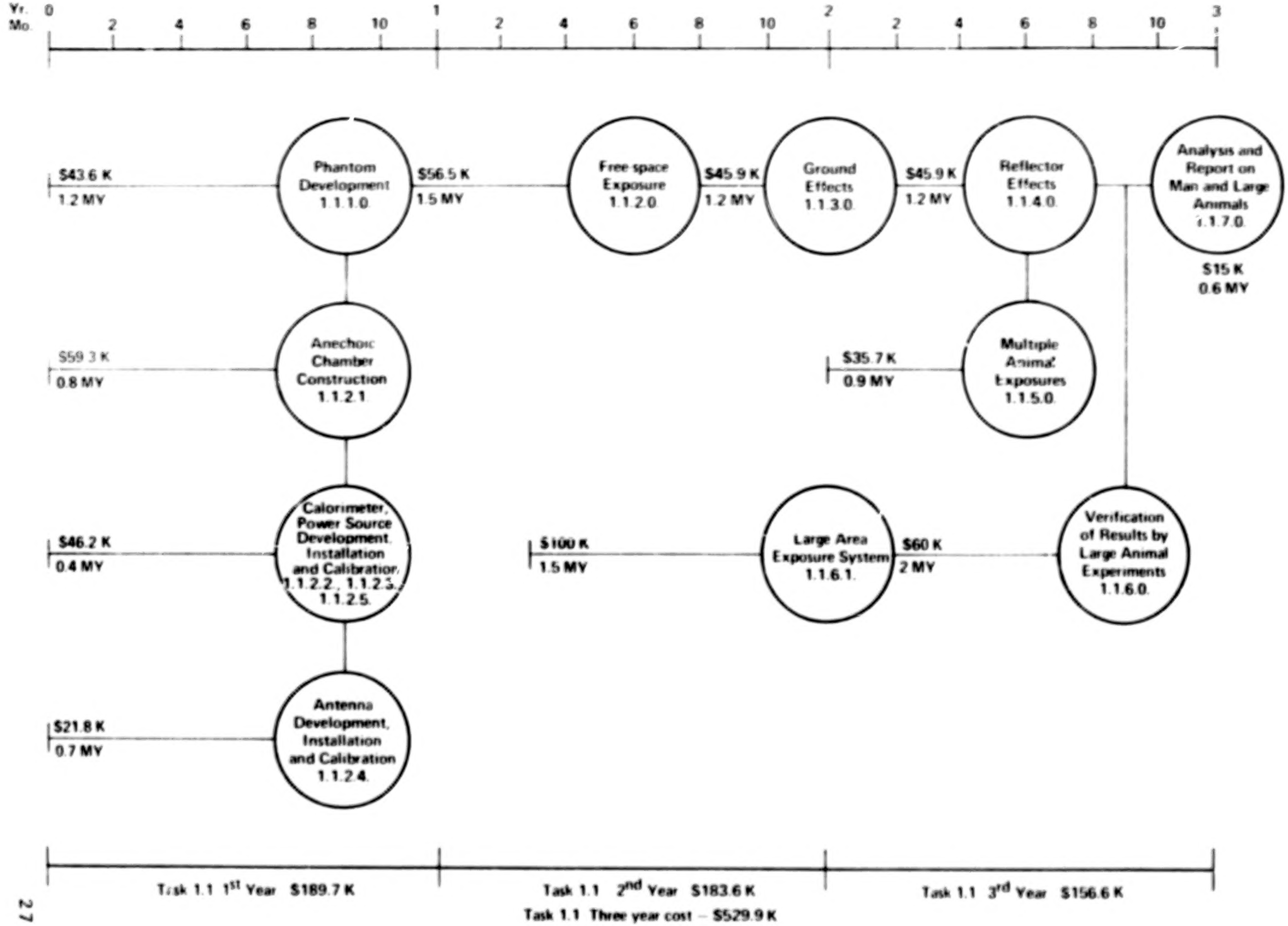

Figure 2

1.2 MICROWAVE ENERGY ABSORPTION IN SMALL ANIMALS

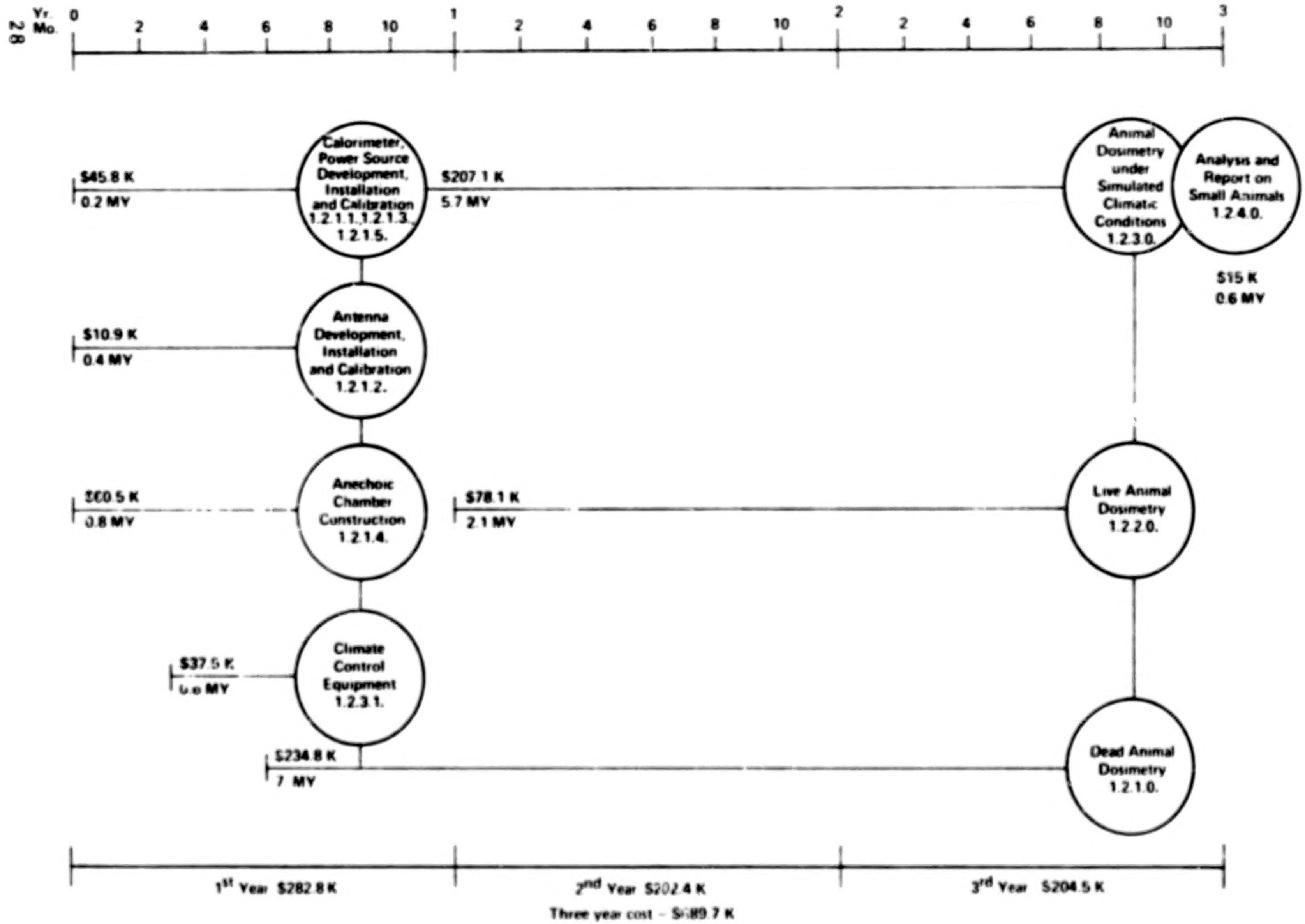

Figure 3

PROTOCOLS

TABLE 3

1.1 MICROWAVE ENERGY ABSORPTION IN MAN AND LARGE ANIMALS

PROTOCOL 1.1.1.0 PHANTOM MODELLING

- o HYPOTHESIS OR TASK: DEVELOP PHANTOM MATERIALS FOR EXPERIMENTATION WITH 1/4TH SCALE MODELS OF MAN, COW, PIG, ETC., IN ORDER TO OBTAIN ENERGY DEPOSITION AND ITS DISTRIBUTION FOR FULL SIZE.
- o APPROACH: THE MATERIALS WILL SIMULATE COMPLEX PERMITTIVITY OF THE BIOLOGICAL TISSUE AT 2450 MHz. MEASUREMENTS WILL BE MADE AT FOUR TIMES THE PROPOSED SPS FREQUENCY OF 2.45 GHz (I.E., AT 9.8 GHz).
- o INFORMATION TO BE DERIVED: GENERATE DATA FOR MAN AND LARGE ANIMALS BY ELECTROMAGNETIC SCALING FROM THE MODELLING EXPERIMENTS.
- o EXPERIMENT TIME:

MONTHS TO COMPLETE	9
MAN YEARS	1.2

- o COST FOR RESEARCH: $43.6K
- o NEW FACILITIES REQUIRED:

TYPE	COST$	MAN YEARS	TIME TO ACQUIRE
NONE			

TABLE 4

1.1 MICROWAVE ENERGY ABSORPTION IN MAN AND LARGE ANIMALS

PROTOCOL 1.1.2.0 FREE SPACE EXPOSURE

- <u>HYPOTHESIS OR TASK</u>: DETERMINATION OF ENERGY DEPOSITION AND ITS DISTRIBUTION IN PHANTOM MODELS UNDER "FREE SPACE" EXPOSURE CONDITION TO PROVIDE BASELINE DATA.
- <u>APPROACH</u>: MEASUREMENT OF WHOLE BODY AND LOCAL SPECIFIC ABSORPTION RATES (SAR) USING THE 1/4TH SCALE MODELS OF TASK 1.1.1 AT 9.8 GHz UNDER CONDITIONS OF ANECHOIC EXPOSURE; ALSO NUMERICAL SOLUTIONS OF ELECTROMAGNETIC ENERGY DEPOSITION FOR REALISTIC MODELS FOR COMPARISON WITH EXPERIMENTAL DATA.
- <u>INFORMATION TO BE DERIVED</u>: GENERATE DATA FOR MAN AND LARGE ANIMALS BY EXTRAPOLATION FROM MODELLING EXPERIMENTS.
- EXPERIMENT TIME:
  - MONTHS TO COMPLETE 9
  - MAN YEARS 1.5
- <u>COST FOR RESEARCH</u>: $56.5K
- <u>NEW FACILITIES REQUIRED</u>:
  (COMMON WITH 1.1.3, 1.1.4, AND 1.1.5)

	TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
1.1.2.1	ANECHOIC CHAMBER	59.3K	0.8	9 MONTHS
1.1.2.2	9800 MHz POWER SOURCE	15.2K	0.2	9 MONTHS
1.1.2.3	RADIATION MONITOR, POWER METER, FREQUENCY METER, OTHER X-BAND COMPONENTS	24.5K	0.2	9 MONTHS
1.1.2.4	"CONSTANT INTENSITY" ANTENNA DESIGN, FABRICATION AND TESTING	21.8K	0.7	9 MONTHS
1.1.2.5	SEEBECK GRADIENT LAYER CALORIMETER	6.5K	---	9 MONTHS

TABLE 5

1.1 MICROWAVE ENERGY ABSORPTION IN MAN AND LARGE ANIMALS

PROTOCOL 1.1.3.0 GROUND EFFECTS

- o HYPOTHESIS OR TASK: DETERMINATION OF GROUND EFFECTS ON THE ENERGY DEPOSITION AND ITS DISTRIBUTION IN PHANTOM MODELS.
- o APPROACH: A PERFECT CONDUCTIVITY (METAL SHEET) AND THREE SOIL CONDUCTIVITIES WILL BE TESTED (OBTAINED BY MIXTURES OF CLAY, SAND, SALT, AND WATER).
- o INFORMATION TO BE DERIVED: DETERMINATION OF THE FACTORS TO BE INCORPORATED INTO THE ENERGY ABSORPTION MODEL FOR PRESENCE OF THE GROUND PLANE.
- o EXPERIMENT TIME:

MONTHS TO COMPLETE	6 MONTHS
MAN YEARS	1.2

- o COST FOR RESEARCH: $45.9K
- o NEW FACILITIES REQUIRED:

TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
COMMON WITH 1.1.2.0			

TABLE 6

1.1 MICROWAVE ENERGY ABSORPTION IN MAN AND LARGE ANIMALS

PROTOCOL 1.1.4.0 REFLECTOR EFFECTS

- o HYPOTHESIS OR TASK: PILOT EXPERIMENTS INDICATE THAT ENERGY DEPOSITION MAY BE INCREASED SEVERAL FOLD BY PRESENCE OF REFLECTORS. VERIFICATION AND QUANTIFICATION OF THIS FACTOR ARE NEEDED.
- o APPROACH: COMPARISON WILL BE MADE OF ENERGY DEPOSITION IN 1/4TH SCALE MODELS EXPOSED TO FLAT REFLECTORS OF SOLID AND GRID CONSTRUCTION OF VARIOUS DIMENSIONS TO THAT UNDER FREE-SPACE EXPOSURE CONDITIONS.
- o INFORMATION TO BE DERIVED: DETERMINATION OF THE ENHANCEMENT FACTORS TO BE INCLUDED IN ABSORBED DOSE FOR REFLECTORS.
- o EXPERIMENT TIME:

MONTHS TO COMPLETE	6 MONTHS
MAN YEARS	1.2

- o COST OF RESEARCH: $45.9K
- o NEW FACILITIES REQUIRED:

TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
COMMON WITH 1.1.2.0			

TABLE 7

1.1 MICROWAVE ENERGY ABSORPTION IN MAN AND LARGE ANIMALS

PROTOCOL 1.1.5.0 MULTIPLE ANIMAL EXPOSURES

- o HYPOTHESIS OR TASK: SIMULTANEOUS EXPOSURE OF MULTIPLE ANIMALS MAY INCREASE ENERGY DEPOSITION IN EACH OF THE TARGETS.
- o APPROACH: MEASURE WHOLE BODY ABSORPTION AND PATTERNS OF ENERGY DEPOSITION IN MULTIPLE PHANTOM MODELS FOR VARIOUS GEOMETRIES.
- o INFORMATION TO BE DERIVED: SCALING FACTORS WILL BE USED TO ASSESS THE EFFECTS OF MULTIPLE ANIMAL EXPOSURE IN ORDER TO INCORPORATE THIS PARAMETER INTO THE DOSE MODEL.
- o EXPERIMENT TIME:

MONTHS TO COMPLETE	6 MONTHS
MAN YEARS	0.9

- o COST FOR RESEARCH: $35.7K
- o NEW FACILITIES REQUIRED:

TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
COMMON WITH 1.1.2.0			

TABLE 8

1.1 MICROWAVE ENERGY ABSORPTION IN MAN AND LARGE ANIMALS

PROTOCOL 1.1.6.0 VERIFICATION OF RESULTS BY EXPERIMENTS WITH LARGE ANIMALS

- HYPOTHESIS OR TASK: SOME OF THE INTERESTING HIGHLIGHTS OF THE ENERGY DEPOSITION IN MAN AND LARGE ANIMALS WILL BE VERIFIED BY EXPERIMENTS WITH ANIMALS AND FULL-SCALE PHANTOMS OF MAN.
- APPROACH: LIVE ANIMALS AND FULL-SCALE PHANTOM MODELS OF MAN WILL BE EXPOSED TO IRRADIATION AT 2450 MHz MAKING USE OF PRESENT GOVERNMENT CAPABILITIES (AT GOLDSTONE). WHOLE BODY ELECTROMAGNETIC DEPOSITION RATES WILL BE MEASURED UNDER SELECTED EXPOSURE CONDITIONS AND COMPARED WITH VALUES OBTAINED FROM MODELLING PROCEDURES.
- INFORMATION TO BE DERIVED: TO CHECK THE ADEQUACY OF MODELLING TO OBTAIN DOSE RATES FOR MAN AND LARGE ANIMALS.
- EXPERIMENT TIME:

MONTHS TO COMPLETE	9 MONTHS
MAN YEARS	2

- COST FOR RESEARCH: $60K
- NEW FACILITIES REQUIRED:

	TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
1.1.6.1	2.45 GHz LARGE AREA EXPOSURE SYSTEM (MODIFICATION OF PRESENT GOVERNMENT FACILITIES AT GOLDSTONE, CALIFORNIA)	$100K	1.5	9 MONTHS

35

TABLE 9

1.1 MICROWAVE ENERGY ABSORPTION IN MAN AND LARGE ANIMALS

PROTOCOL 1.1.7.0 ANALYSIS AND REPORT FOR 1.1.1.0 THROUGH 1.1.5.0

- HYPOTHESIS OR TASK: FROM RESULTS OF MODELLING EXPERIMENTS UNDER FREE SPACE, GROUND PLANE, REFLECTOR EFFECTS, AND MULTIPLE ANIMAL EXPOSURES, RELATIONSHIPS WILL BE DEVELOPED AND REPORTED FOR ENERGY DEPOSITION IN MAN AND LARGE ANIMALS AT 2.45 GHz. NUMERICAL SOLUTIONS OF ELECTROMAGNETIC ENERGY DEPOSITION WILL BE OBTAINED AND COMPARED WITH EXPERIMENTAL RESULTS. A MAJOR THRUST OF THE TASK WILL BE TO OBTAIN GENERALIZATION TO OTHER LARGE ANIMAL SPECIES AND EXPOSURE CONDITIONS.
- APPROACH: USE OF PROPER SCALING PROCEDURES TO OBTAIN RATES OF ENERGY DEPOSITION FOR MAN AND LARGE ANIMALS UNDER VARIOUS EXPOSURE CONDITIONS AND EXTENSION OF NUMERICAL TECHNIQUES TO OBTAIN MATHEMATICAL RESULTS FOR COMPARISON.
- INFORMATION TO BE DERIVED: TO PRESCRIBE ABSORBED ELECTROMAGNETIC DOSE AND ITS DISTRIBUTION FOR MAN AND LARGE ANIMALS THAT ARE SUBJECTED TO 2450 MHz RADIATION UNDER VARIOUS EXPOSURE CONDITIONS.
- EXPERIMENT TIME:

MONTHS TO COMPLETE	3 MONTHS
MAN YEARS	0.6

- COST FOR RESEARCH: $15K
- NEW FACILITIES REQUIRED:

TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
NONE			

TABLE 10

1.2 MICROWAVE ENERGY ABSORPTION IN SMALL ANIMALS

PROTOCOL 1.2.1.0 DEAD ANIMAL DOSIMETRY

- <u>HYPOTHESIS OR TASK</u>: BASED ON PREVIOUS WORK, ABSORPTION OF 2450 MHz MICROWAVES SHOULD BE GREATEST FOR SMALL ANIMALS OF 5 TO 6 CM (0.4λ) FOR $\vec{E} \parallel \vec{L}$ ORIENTATION. DOSE RATES MAY ALSO BE ALTERED CONSIDERABLY BY CONDUCTIVITY OF GROUND PLANE, REFLECTING SURFACES, AND OTHER ANIMALS.
- <u>APPROACH</u>: DETERMINE ABSORBED DOSE BY DEAD ANIMAL CALORIMETRY ON SEVERAL SPECIES REPRESENTATIVE OF RECTENNA SITES. EXPERIMENTS WILL BE CONDUCTED AT 2450 MHz FOR THREE ORIENTATIONS ($\vec{E} \parallel \vec{L}$, $\vec{K} \parallel \vec{L}$, AND $\vec{H} \parallel \vec{L}$) IN FREE SPACE EXPOSURE, IN PRESENCE OF GROUND PLANES OF PERFECT CONDUCTIVITY (METAL SHEET) AND THREE REPRESENTATIVE SOIL CONDUCTIVITIES, AND IN PRESENCE OF REFLECTORS OF VARIOUS DIMENSIONS, AND OTHER ANIMALS.
- <u>INFORMATION TO BE DERIVED</u>: QUANTIFY THE ABSORBED MICROWAVE ENERGY FOR VARIOUS SPECIES UNDER DIFFERENT EXPOSURE CONDITIONS.
- <u>EXPERIMENT TIME</u>:
  - MONTHS TO COMPLETE 27
  - MAN YEARS 7.0
- <u>COST FOR RESEARCH</u>: $234.8K
- <u>NEW FACILITIES REQUIRED</u>:

	TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
1.2.1.1	5 kW, 2450 MHz POWER SOURCE	17.7K	0.2	9 MONTHS
1.2.1.2	ANTENNA DEVELOPMENT	10.9K	0.4	9 MONTHS
1.2.1.3	CALORIMETER & RECORDER	8.8K	---	9 MONTHS
1.2.1.4	ANECHOIC CHAMBER	60.5K	0.8	9 MONTHS
1.2.1.5	POWER & FREQUENCY MONITORS	19.3K	0.2	9 MONTHS

TABLE 11

1.2 MICROWAVE ENERGY ABSORPTION IN SMALL ANIMALS

PROTOCOL 1.2.2.0 LIVE ANIMAL DOSIMETRY

- o HYPOTHESIS OR TASK: FREEDOM OF MOVEMENT MAY CONSIDERABLY ALTER THE SPECIFIC ABSORPTION RATE OF 2450 MHz MICROWAVES AS COMPARED TO DEAD ANIMAL EXPOSURES.
- o APPROACH: WHILE DEAD ANIMAL DOSIMETRY HELPS TO ESTABLISH THE BASELINES, LIVE ANIMAL DOSIMETRY IS ALSO PERTINENT. IN THIS CASE THE ANIMAL IS NEVER PERFECTLY PARALLEL TO ANY OF THE ORIENTATIONS STUDIED IN 1.2.1.0. A RECENT STUDY HAS SHOWN THAT CORTONE ACETATE TREATED RODENTS DO NOT THERMOREGULATE A PREFERRED BODY TEMPERATURE AND APPEAR ECTOTHERMIC. THIS TECHNIQUE WILL BE ADAPTED FOR LIVE ANIMAL DOSIMETRY.
- o INFORMATION TO BE DERIVED: TO QUANTIFY THE AMOUNT OF ABSORBED 2450 MHz MICROWAVES FOR LIVE AWAKE ANIMALS UNDER DIFFERENT EXPOSURE CONDITIONS.
- o EXPERIMENT TIME:

MONTHS TO COMPLETE	21
MAN YEARS	2.1

- o COST FOR RESEARCH: $78.1K
- o NEW FACILITIES REQUIRED:

TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
COMMON WITH 1.2.1.0.			

1.2 MICROWAVE ENERGY ABSORPTION IN SMALL ANIMALS

PROTOCOL 1.2.3.0 SMALL ANIMAL DOSIMETRY UNDER SIMULATED CLIMATIC CONDITIONS

- o HYPOTHESIS OR TASK: THE ANIMALS' CAPABILITY TO DISSIPATE MICROWAVE-INDUCED HEAT LOAD WILL VARY AS TEMPERATURE AND HUMIDITY CHANGE. FOR HIGH HUMIDITIES AT ELEVATED TEMPERATURES, THE ANIMALS' INABILITY TO DISSIPATE MICROWAVE-INDUCED HEAT MAY CONTRIBUTE TO REDUCED SURVIVAL TIMES.
- o APPROACH: SELECTED SPECIES WILL BE ADAPTED TO EACH OF THE SIMULATED CLIMATIC CONDITIONS (A) 21° C, 30 PERCENT RH; (B) 33° C, 15 PERCENT RH; (C) 33° C, 75 PERCENT RH; AND (D) 5° C, 15 PERCENT RH) FOR 2 TO 3 WEEKS. EACH ANIMAL WILL THEN BE EXPOSED TO MICROWAVE IRRADIATION UNDER REPRESENTATIVE EXPOSURE CONDITIONS. BEFORE AND AFTER BODY TEMPERATURES WILL BE RECORDED AND SPECIFIC ABSORPTION RATES CALCULATED. SURVIVAL TIME OF EACH OF THE SPECIES UNDER THESE CONDITIONS WILL ALSO BE STUDIED.
- o INFORMATION TO BE DERIVED: MICROWAVE-INDUCED ANIMAL BODY TEMPERATURE RISE WILL BE QUANTIFIED UNDER FOUR CLIMATIC CONDITIONS FOR FREE SPACE AS WELL AS REFLECTOR AND GROUND EXPOSURE CONDITIONS. THE DATA GATHERED HERE MAY ALSO GIVE THE SURVIVABILITY OF VARIOUS SPECIES.
- o EXPERIMENT TIME:
  - MONTHS TO COMPLETE: 24
  - MAN YEARS: 5.7
- o COST FOR RESEARCH: $207.1K
- o NEW FACILITIES REQUIRED:

	TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
1.2.3.1	CLIMATE CONTROL EQUIPMENT	$37.5K	0.6	9 MONTHS

TABLE 13

40

1.2 MICROWAVE ENERGY ABSORPTION IN SMALL ANIMALS

PROTOCOL 1.2.4.0 ANALYSIS AND REPORT FOR 1.2.1.0 THROUGH 1.2.3.0

- HYPOTHESIS OR TASK: FROM RESULTS OF EXPERIMENTS ON VARIOUS SPECIES OF DEAD AND ALIVE ANIMALS UNDER VARIOUS EXPOSURE CONDITIONS (WITH AND WITHOUT GROUND PLANE, REFLECTORS, AND OTHER NEARBY ANIMALS), GENERALIZED RELATIONSHIPS WILL BE DEVELOPED AND REPORTED. NUMERICAL SOLUTIONS OF ELECTROMAGNETIC ENERGY DEPOSITION WILL BE OBTAINED AND COMPARED WITH EXPERIMENTAL RESULTS. A MAJOR THRUST OF THIS WORK WILL BE TO OBTAIN GENERALIZED RELATIONSHIPS THAT WILL BE APPLICABLE TO OTHER SPECIES AS WELL.
- APPROACH: USE OF ELECTROMAGNETIC SCALING PROCEDURES TO OBTAIN RATES OF ENERGY DEPOSITION FOR VARIOUS SMALL ANIMAL SPECIES UNDER DIFFERENT EXPOSURE CONDITIONS.
- INFORMATION TO BE DERIVED: TO PRESCRIBE ABSORBED ELECTROMAGNETIC DOSE FOR SMALL ANIMALS THAT ARE SUBJECTED TO 2450 MH_Z RADIATION UNDER VARIOUS EXPOSURE CONDITIONS.
- EXPERIMENT TIME:

MONTHS TO COMPLETE	3
MAN YEARS	0.6

- COST FOR RESEARCH: $15K
- NEW FACILITIES REQUIRED:

TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
COMMON WITH 1.2.1.0.			

MILESTONE AND FUNDING SUMMARY

TABLE 14

MILESTONE AND FUNDING SUMMARY

	PHASE A YEAR 0 1 2 3	COST $K Exper.	Facil.	Question
1.1.0.0 Microwave Energy Absorption in Man and Large Animals	▽	--	---	531
1.1.1.0 Phantom Development	▽	44	---	
1.1.2.0 Free-space Exposure	▽	57	127	
1.1.3.0 Ground Effects	▽	46	---	
1.1.4.0 Reflector Effects	▽	46	---	
1.1.5.0 Multiple Animal Exposures	▽	36	---	
1.1.6.0 Verification	▽	60	100	
1.1.7.0 Analysis and Report	▽	15	---	
1.2.0.0 Microwave Energy Absorption in Small Animals	▽	--	---	690
1.2.1.0 Dead Animal Dosimetry	▽	235	117	
1.2.2.0 Live Animal Dosimetry	▽	78	---	
1.2.3.0 Dosimetry under Simulated Climatic Conditions	▽	207	38	
1.2.4.0 Analysis and Report	▽	15	---	

PILOT EXPERIMENTATION

A 2450 MHz horn antenna with aperture of dimensions 49.0 by 34.3 cm has been designed and fabricated for a measured ±0.5 dB beam width of ±6.3° in both E- and H-planes. The measured pattern is in conformity with theoretical calculations based on Jakes (12) and also Jull (13). For a 500-watt input, a relatively constant (within ±0.5 dB) field intensity of 120 mW/cm^2 is measured over a zone of 30 by 30 cm at a distance of 1.37 m from the aperture of the radiating horn antenna. The distance of 1.27 m is somewhat less than the preferred "far-field" distance of D^2/λ or 1.96 m. However, due to the limited size of the anechoic chamber (2.74 by 2.48 by 1.7 m) and limited available power (500-W magnetron) at CW 2.45 GHz, the present distance was chosen to provide a fairly high power density that is needed to produce a rapid animal temperature rise to ensure accurate calorimetric measurements. The horn antenna was positioned to provide a 45° incidence relative to the horizontal plane of the chamber. For irradiation, anesthetized animals are placed on a styrofoam platform with the length of the animal parallel to the electric field ($\vec{E}\,||\,L$ orientation). Larger anechoic chambers and higher power magnetrons will be required for the three-year project to allow distances to the horn larger than $2D^2/\lambda$ which will also then give wider working areas of relatively constant power density.

Preliminary SAR data for six species of animals tested in the pilot phase of the project are given in Table 2. Also shown for comparison are the calculated values from the empirical equation (1). The measured values of SAR agree well with those calculated from the empirical equation. A few data points on whole-body absorbed dose have also been obtained with the Thermonetics model SEC2401A calorimeter. These are also listed in Table 2 for comparison. The correlation with the values obtained on the basis of rectal temperature measurements is fairly good. A couple of other points to note from Table 2 are:

a. For ring doves, the SARs projected from the empirical equation are considerably lower than those measured experimentally. The reason for this discrepancy is not clear at this time.

b. For lizards, the body is gradually tapering. The tail which generally is quite long, is not negligible for this species. The measured value of SAR has been used to calculate a microwave effective length of the animal from the empirical equation.

The microwave effective length of the animal is about 50 percent of the overall length.

As previously mentioned, the empirical equation for SAR for $\vec{E}||L$ free-space irradiation for the frequency region $f_r < f < (1.6\ S_{res})\ f_r$ is in fairly good agreement with experimental data. For the supraresonant region, the SAR for the other two configurations $\vec{k}||L$ and $\vec{H}||L$ is not known. Also SAR for nonfree-space irradiation conditions is not known.

IV. CHRONIC LOW-LEVEL EFFECTS

FROM CW 2.45 GHz MICROWAVES*

SIGNIFICANCE OF CATEGORY

Over the past decade, scientists, radiation safety specialists, and various government officials concerned with the biological effects of electromagnetic fields have become increasingly aware of the large differences in research results and safety standards of the United States and Western countries on one side, and the USSR and East European countries on the other side. In spite of a large increase in funding of research in this country, the Soviet Union, and Eastern Europe over the past several years, no acceptable answers have been found to the questions of why such large differences should exist between the scientific results from the various countries. These large differences in research results are causing many problems, with increasing pressure on lowering safety standards, both in the United States and the Western countries, which could have significant impact on the SPS program.

One of the most striking differences in research approaches between the U. S. and the USSR became very evident from a Symposium held in Warsaw, Poland, on Biological Effects of Electromagnetic Fields and the exchange visits that followed. A large percentage of the Soviet work is based on long-term chronic exposure of test animals at relatively low power levels, whereas most of the research in the U. S. is directed toward the acute short-term type exposures, usually at much higher power levels. Therefore, in order to resolve these differences, considerable priority must be placed on types of experiments involving the chronic exposure of various test animals, especially using protocols that have already produced low-level effects as observed by the Soviet scientists.

A group of scientists at the Kiev Institute of General and Communal Hygiene, directed by Professor Shandala, is the Soviet group responsible for providing the data and recommendations for

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*Abstracted from the Final Report for Ames Research Center, NASA Contract NAS2-9536 "Biologcial and Ecological Effects of Energy Transmission by Microwaves - Chronic Low-Level Effects", Arthur W. Guy, Vernon T. Riley, Chung-Kwang Chou, Richard H. Levely, and Darrel H. Spackman, University of Washington, December 15, 1977

microwave standards for the general population. The Soviet standard of 0.1 mW/cm^2 for eight hour exposures is really an occupational safety standard and was developed by the various institutes for occupational health and disease. Professor Shandala, feels the safety standard for the general population should be an order of magnitude greater, and seems to be aiming his research program to provide data for substantiating this statement. In most cases, the Soviet standards are usually set at least a factor of ten or more below the point where biological effects are observed. Professor Shandala reported effects from exposure levels as low as .01 mW/cm^2, supporting his view that the safety standard should be .001 mW/cm^2, or below. Unfortunately, there is no data available from America to challenge these results.

Soviet and American work, is now under close scrutiny by the USSR Academy of Sciences in an attempt to learn why there exists such large differences between the safety standards of the two countries. It appears that the USSR Academy of Sciences is concerned about the safety standard going to levels of .001 mW/cm^2, or lower. They are now replicating some of the American experiments and adapting some of the American techniques in an attempt to find the mechanisms of the low-level effects that their colleagues in the Ministry of Health are getting. So American work replicating Soviet experiments could have significant influence on the Soviets and play an important part in the final outcome of safety standards in both countries.

The research program outlined in this section is formulated to maximize the information that can be obtained in a three year period under Phase A, specifically needed to help resolve questions relating to the differences between research results and safety standards accepted by the United States and Eastern Europe. In addition, the program is formulated to replicate, under well-controlled exposure and environmental conditions, some of the low-level effects most often reported in the United States. The research program is directed toward the study of biological effects on the mammalian system utilizing mice, rats, and rabbits as laboratory subjects. These animals represent the type of mammalian subjects expected to be exposed in the vicinity of an SPS receiving antenna site.

PRIORITIZED LIST OF QUESTIONS

1. WHAT ARE THE EFFECTS OF MICROWAVE ILLUMINATION ON THE MAMMALIAN IMMUNOLOGICAL SYSTEM?

Disturbances of the immunological system are the second most frequently observed effects of microwave illumination reported in the East European literature. This is also the one area in which recent investigations in the United States have confirmed earlier reports by Soviet and Polish researchers. The effects on the immunological system need to be explored thoroughly. Since the stress could be an essential parameter, which was neglected by most researchers, for explaining the observed biological effects of microwaves, it is important that this work be carried out under well-controlled conditions.

2. WHAT ARE THE EFFECTS OF MICROWAVE ILLUMINATION ON THE RABBIT EEG, AS WELL AS CHEMICAL, CYTO-CHEMICAL, AND IMMUNOLOGICAL PROPERTIES IN BLOOD?

Professor Sandala's experiment on low-level exposure of rabbits should be replicated under better controlled conditions, since his results will have high priority in the promulgation and enforcement of Soviet safety standards applied to the general population. Other considerations are the multiple endpoints with minimum cost based on the utilization of existing exposure facilities.

3. DOES MICROWAVE ILLUMINATION ALTER ANY BIOLOGICAL MEMBRANE PERMEABILITY?

The effects of low-level microwave illumination on the blood-brain barrier, has been a controversial issue. The importance of the blood-brain barrier in protecting the central nervous system from circulating toxic substances in blood is well recognized. A modification of this system by microwave illumination critically influences the physiology of the animals. Effects on the permeability of other membranes, peritoneal and placental membranes should also be investigated.

4. WHAT ARE THE EFFECTS OF MICROWAVE ILLUMINATION ON BEHAVIOR?

A large number of Soviet and US reports indicate behavioral changes in animals exposed to low-level microwave radiation. This work, however, should be replicated utilizing better exposure techniques and well controlled environmental conditions to eliminate possible artifactual results.

5. WHAT ARE THE EFFECTS OF MICROWAVE ILLUMINATION ON REPRODUCTION?

To answer this question, the research should include studies on teratology, fertility, fecundity, growth, and development. The developing embryo and fetus are known to be the most sensitive form of life for the induction of health effects by ionizing radiation and many other environmental pollutants. Soviet investigators have reported teratologic effects in animals chronically exposed to microwaves. The effects on developing insects have been replicated by three independent laboratories. This work should be extended to mammalian systems. Further replication of the pupi is not needed in Phase A, but there is evidence that the effects may be due to some "hot spots" and thermal gradients characteristic only to systems without blood circulation. A study on the reproduction of animals exposed multi-generationally needs to be explored.

PLANNING CHARTS

2.0.0.0. CHRONIC LOW-LEVEL EFFECTS

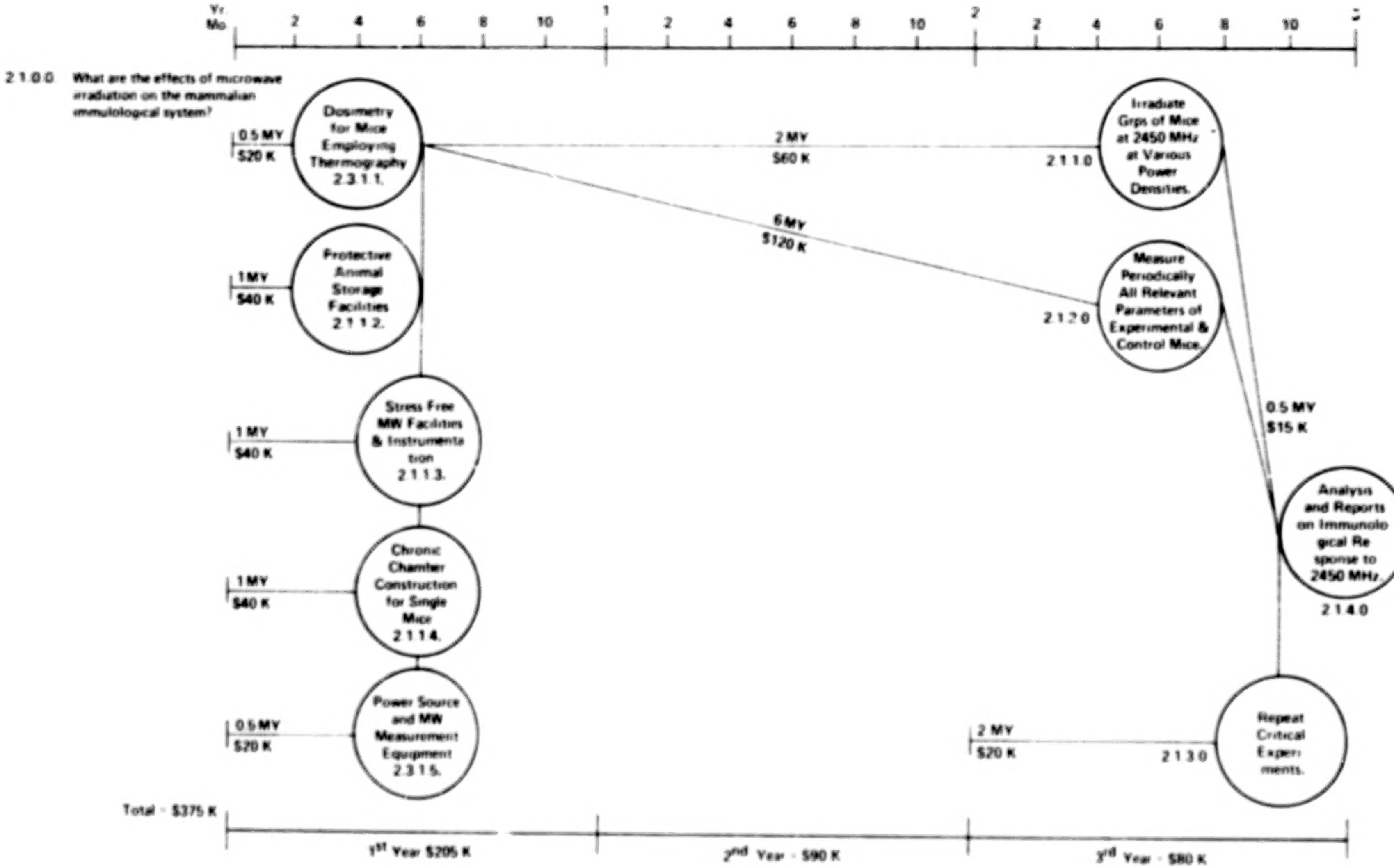

Figure 4

2.0.0.0. CHRONIC LOW-LEVEL EFFECTS

2.2 What are the effects of microwave irradiation on the rabbit EEG, patterns as well as chemical, pseudo chemical and immunological properties in blood?

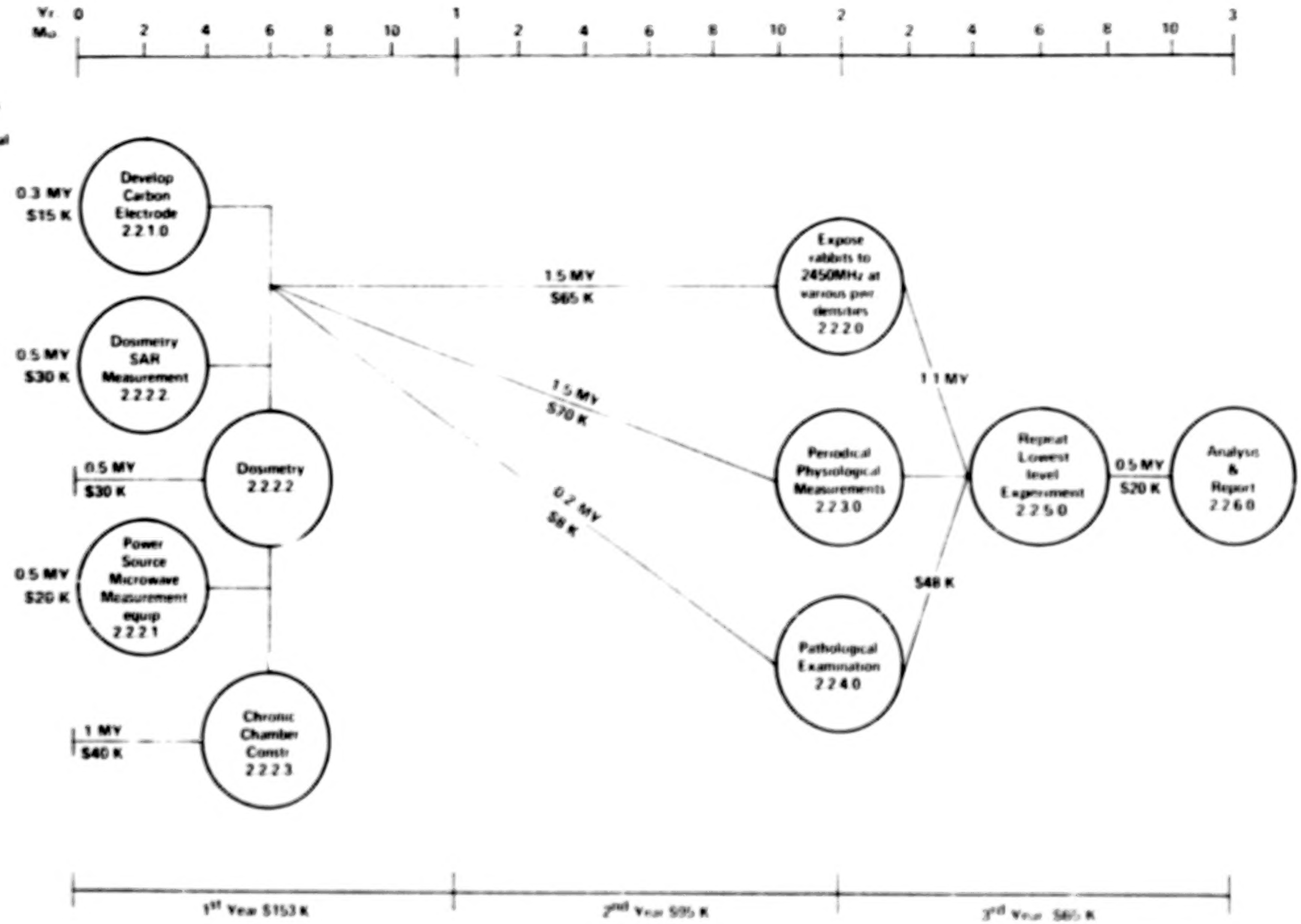

Figure 5

2.0.0.0. CHRONIC LOW-LEVEL EFFECTS

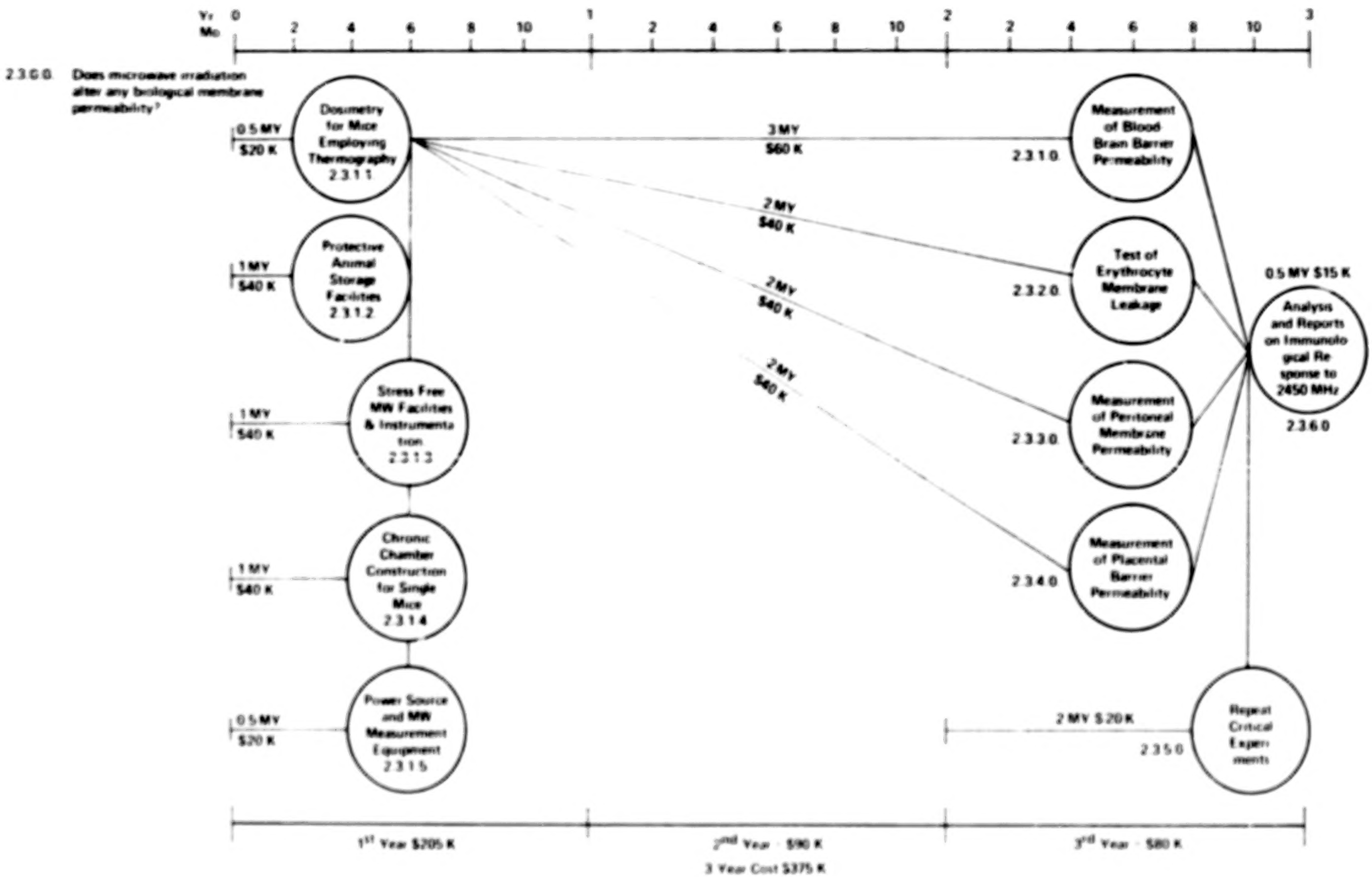

Figure 6

2.0.0.0. CHRONIC LOW-LEVEL EFFECTS

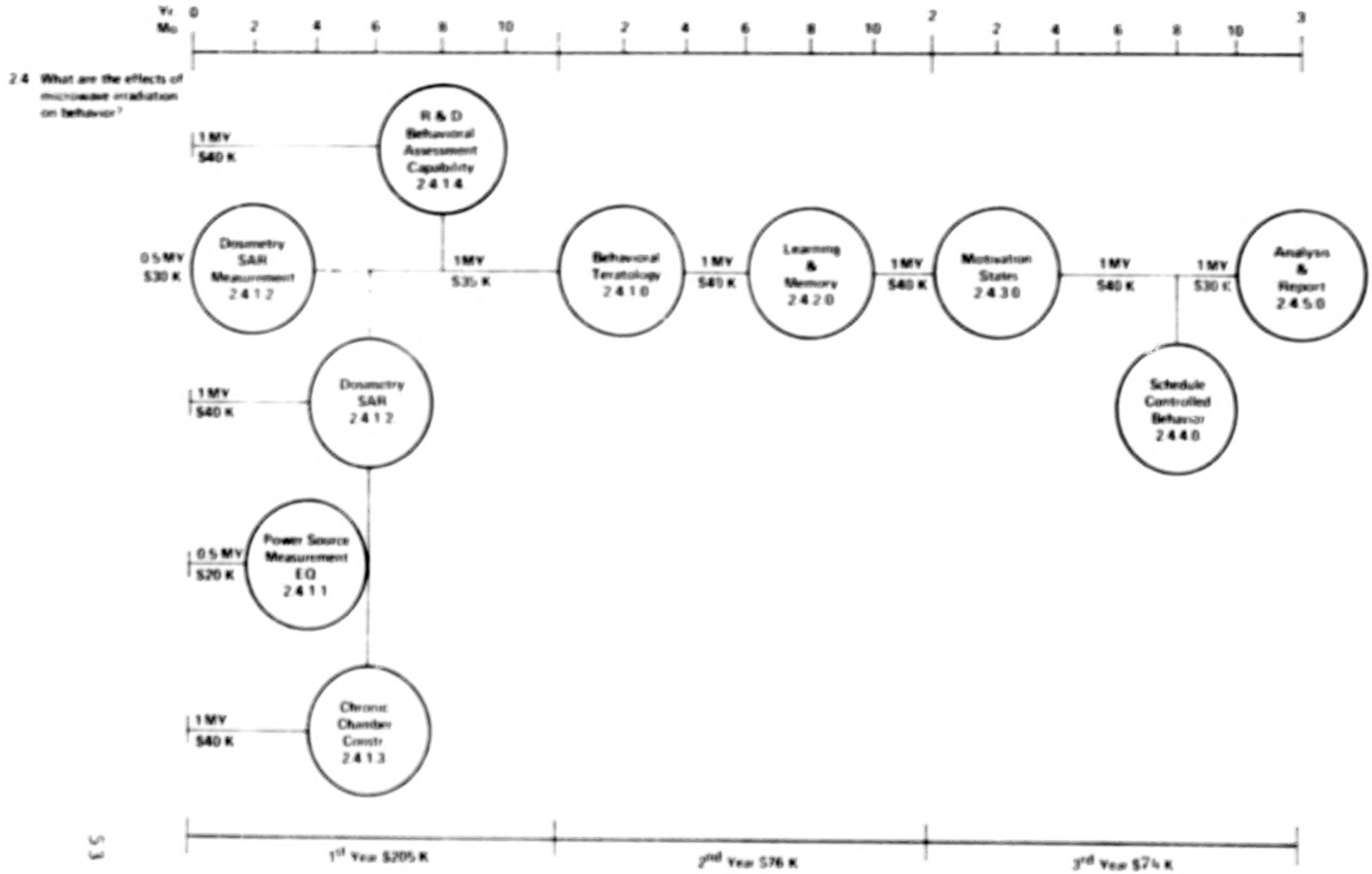

Figure 7

2.0.0.0. CHRONIC LOW-LEVEL EFFECTS

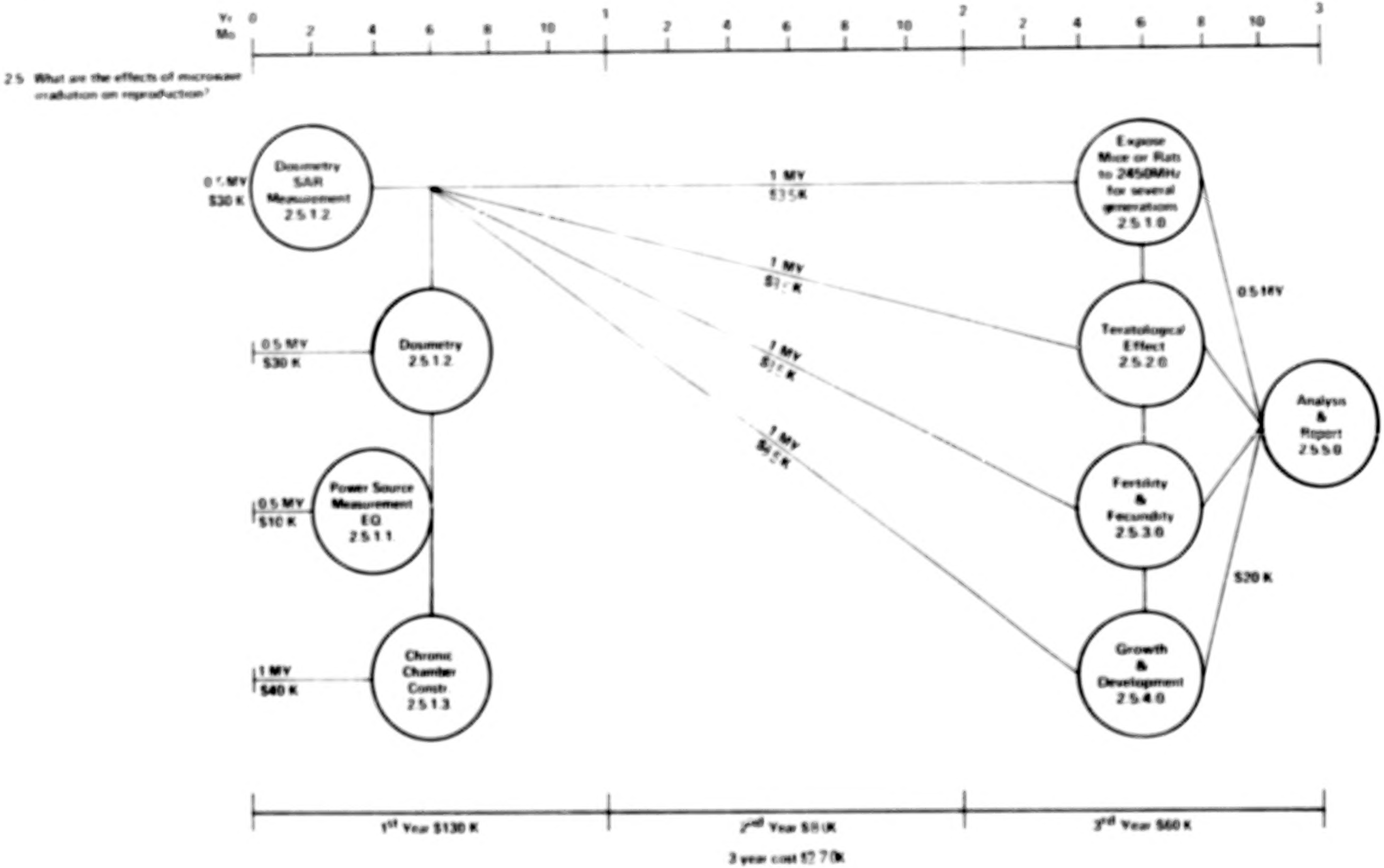

Figure 8

PROTOCOLS

TABLE 15

2.1 WHAT ARE THE EFFECTS OF MICROWAVE IRRADIATION ON THE MAMMALIAN IMMUNOLOGICAL SYSTEM?

PROTOCOL 2.1.1.0 CHRONIC IRRADIATION OF MICE, OR OTHER APPROPRIATE EXPERIMENTAL ANIMALS, AT VARIOUS POWER DENSITIES

- HYPOTHESIS OR TASK: DETERMINE IF MICROWAVE-INDUCED CHANGES OCCUR IN MOUSE T CELLS, B CELLS, MACROPHAGES, OR OTHER RELATED HOST PARAMETERS, SEPARATE AND DISTINCT FROM ALTERATIONS KNOWN TO BE CAUSED BY EXPERIMENTAL HANDLING OR ENVIRONMENTAL STRESS, AND OBTAIN THRESHOLD LEVELS.
- APPROACH: INITIATE CHRONIC 2.45 GHz, 1 mW/cm^2 IRRADIATION OF MICE, OR OTHER ANIMALS, UNDER CONDITIONS THAT MINIMIZE STRESS AND OTHER FACTORS THAT MAY INTRODUCE ARTIFACTS. IF REPRODUCIBLE EFFECTS ARE OBTAINED, THE MW DOSE SHALL BE DECREASED UNTIL A THRESHOLD VALUE IS OBTAINED. IF NO EFFECTS ARE OBSERVED AT 1 mW/cm^2, 2-FOLD MW INCREASES WILL BE ADMINISTERED UNTIL EFFECTS ARE OBSERVED.
- INFORMATION TO BE DERIVED: QUANTITATE ALTERATIONS (IF ANY) IN THE BIOCHEMICAL, CELLULAR, OR TISSUE COMPONENTS OF MICE. POWER DENSITY THRESHOLDS WILL BE ESTABLISHED FOR SIGNIFICANTLY ALTERED ELEMENTS OF THE IMMUNOLOGICAL SYSTEM.
- EXPERIMENT TIME:
  - MONTHS TO COMPLETE: 24
  - MAN YEARS: 2
- COST FOR RESEARCH: $60K
- NEW FACILITIES REQUIRED:

	TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
2.1.1.1	THERMOGRAPHIC AND POWER DENSITY DISTRIBUTION EQUIPMENT	$20K	0.5	6 MONTHS
2.1.1.2	MINIMAL STRESS HOUSING	$40K	1.0	4 MONTHS
2.1.1.3	MINIMAL STRESS IRRADIATION FACILITIES & INSTRUMENTATION	$40K	1.0	6 MONTHS
2.1.1.4	CHAMBER FOR IRRADIATING SINGLE MICE	$40K	1.0	6 MONTHS
2.1.1.5	MICROWAVE MEASUREMENT EQUIPMENT	$20K	0.5	4 MONTHS

TABLE 16

2.1 WHAT ARE THE EFFECTS OF MICROWAVE IRRADIATION ON THE MAMMALIAN IMMUNOLOGICAL SYSTEM?

PROTOCOL 2.1.2.0 MEASUREMENT OF HORMONAL, CELLULAR, BIOCHEMICAL, AND IMMUNOLOGICAL PARAMETERS

- o HYPOTHESIS OR TASK: EXAMINE EXPERIMENTAL AND CONTROL ANIMALS AT INTERVALS DURING 2.45 GHz MW IRRADIATION FOR ALTERATIONS IN PHYSIOLOGY, BIOCHEMISTRY AND CELLULAR STATES RELATED TO IMMUNOLOGICAL FUNCTION.
- o APPROACH: ANXIETY-STRESS ALTERATIONS PRODUCED BY THE PITUITARY-ADRENAL-THYMUS AXIS WILL BE MEASURED. NECESSARY DATA WILL BE OBTAINED WITHOUT PERTURBING THE MICROWAVE-ASSOCIATED RESULTS BY ANXIETY-STRESS INDUCED WHILE DRAWING BLOOD SAMPLES. TWO CONTROL GROUPS WILL BE EMPLOYED, ANIMALS EXPOSED TO THE SAME HANDLING AS THE IRRADIATED MICE, AND CONTROLS PROVIDED WITH PROTECTION FROM STRESS.
- o INFORMATION TO BE DERIVED: DETERMINE PLASMA CORTICOSTERONE LEVELS AND ORGAN WEIGHTS, EMPHASIZING THE THYMUS, PERIPHERAL NODES, SPLEEN AND ADRENALS, SINCE THESE ARE RELATED TO BOTH STRESS AND IMMUNOCOMPETENCE. IMMUNOLOGICAL COMPETENCE WILL BE DEFINED IN RESPECT TO T CELL AND B CELL RESPONSE AND ABILITY TO COPE WITH AN IMMUNOLOGICAL CHALLENGE.
- o EXPERIMENT TIME:

MONTHS TO COMPLETE	24
MAN YEARS	6

- o COST FOR RESEARCH: $120K
- o NEW FACILITIES REQUIRED:

TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
COMMON WITH 2.1.1.0			

57

TABLE 17

2.1 WHAT ARE THE EFFECTS OF MICROWAVE IRRADIATION ON THE MAMMALIAN IMMUNOLOGICAL SYSTEM?

PROTOCOL 2.1.3.0 EXPERIMENTAL REPETITITION OF CRITICAL OR PROVOCATIVE EXPERIMENTAL FINDINGS

- o HYPOTHESIS OR TASK: TO REPEAT THOSE SELECTED EXPERIMENTS WHICH WILL PROVIDE CONFIRMATION AND AUTHENTICITY TO MICROWAVE THRESHOLD VALUES.
- o APPROACH: REPEAT EXPERIMENTS EXACTLY AS ORIGINALLY DESIGNED, OR BY THE INTRODUCTION OF NEW MODULATIONS WHICH MAY BE REQUIRED BY EARLIER RESULTS.
- o INFORMATION TO BE DERIVED: CONFIRMATION OF THRESHOLD MW VALUES IN RESPECT TO SPECIFIC PHYSIOLOGICAL PARAMETERS.
- o EXPERIMENT TIME:

MONTHS TO COMPLETE	10
MAN YEARS	2

- o COST FOR RESEARCH: $20K
- o NEW FACILITIES REQUIRED:

TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
COMMON WITH 2.1.1.0			

TABLE 18

2.1 WHAT ARE THE EFFECTS OF MICROWAVE IRRADIATION ON THE MAMMALIAN IMMUNOLOGICAL SYSTEM?

PROTOCOL 2.1.4.0 ANALYSIS AND REPORTS ON IMMUNOLOGICAL RESPONSE TO 2450 MHz

- o HYPOTHESIS OR TASK: TO PREPARE FINAL REPORTS AND MANUSCRIPTS FOR PUBLICATION.
- o APPROACH: ANALYZE ACCUMULATED DATA BY APPROPRIATE STATISTICAL ANALYSIS, PREPARE TABLES, CHARTS, AND FIGURES DEPICTING THE ESSENTIAL FINDINGS OF THE STUDY.
- o INFORMATION TO BE DERIVED: ESTABLISH DEFINITIVE INFORMATION ON THE BIOLOGICAL EFFECTS OF 2450 MHz MICROWAVES, AND THE DETERMINATION OF POWER DENSITY THRESHOLDS.
- o EXPERIMENT TIME:

MONTHS TO COMPLETE	6
MAN YEARS	0.5

- o COST FOR RESEARCH: $15K
- o NEW FACILITIES REQUIRED:

TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
NONE			

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TABLE 19

2.2 EFFECTS ON RABBIT EEG PATTERNS, AS WELL AS CHEMICAL CYTO-CHEMICAL AND IMMUNOLOGICAL PROPERTIES IN BLOOD

PROTOCOL 2.2.1.0 DEVELOPMENT OF CARBON ELECTRODES

- HYPOTHESIS OR TASK: CONVENTIONAL METAL ELECTRODES USED IN PHYSIOLOGICAL EXPERIMENTS CAN CAUSE FIELD INTENSIFICATION AT THE TIP OF THE ELECTRODES BY SEVERAL ORDERS OF MAGNITUDE.
- APPROACH: CARBON-LOADED TEFLON WITH CONDUCTIVITY CLOSE TO TISSUE PRODUCES LITTLE FIELD MODIFICATION IN TISSUE. BOTH CORTICAL AND SUBCORTICAL CARBON ELECTRODES WILL BE FABRICATED.
- INFORMATION TO BE DERIVED: FABRICATE SUFFICIENT CORTICAL AND SUBCORTICAL CARBON ELECTRODES FOR THE FOUR PERIODS OF CHRONIC EXPOSURE STUDY.
- EXPERIMENT TIME:

MONTHS TO COMPLETE	4
MAN YEARS	0.3

- COST FOR RESEARCH: $15K
- NEW FACILITIES REQUIRED:

TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
NONE			

TABLE 20

2.2 EFFECTS ON RABBIT EEG PATTERNS, AS WELL AS CHEMICAL, CYTO-CHEMICAL AND IMMUNOLOGICAL PROPERTIES IN BLOOD

PROTOCOL 2.2.2.0 CHRONIC IRRADIATION OF RABBITS AT VARIOUS POWER DENSITIES

- o HYPOTHESIS OR TASK: DETERMINE THE THRESHOLD POWER LEVEL AT WHICH THE CHRONIC EXPOSURE CAUSES PHYSIOLOGICAL EFFECTS ON RABBITS. BASED ON THE SAR MEASUREMENTS, THE RESULTS WILL BE EXTRAPOLATED TO HUMANS FOR SAFETY STANDARDS.
- o APPROACH: 16 RABBITS (8 EXPOSED, 8 CONTROL) WILL BE EXPOSED 8 HOURS DAILY TO 0.5 mW/cm^2, 2450 MHz CW, FOR A PERIOD OF 3 MONTHS. THE SUBSEQUENT LEVEL WILL BE EITHER 5 OR 0.05 mW/cm^2, DEPENDING ON THE RESULTS OF THE FIRST PERIOD. THE LEVEL OF THE THIRD PERIOD WILL BE EITHER 10, 1, 0.1 OR 0.01 mW/cm^2.
- o INFORMATION TO BE DERIVED: FIND THE THRESHOLD INCIDENT POWER DENSITY FOR RABBITS. EXTRAPOLATION TO HUMANS CAN BE DERIVED FROM THESE DATA.
- o EXPERIMENT TIME:

MONTHS TO COMPLETE	18
MAN YEARS	1.5

- o COST FOR RESEARCH: $65K
- o NEW FACILITIES REQUIRED:

	TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
2.2.2.1	POWER SOURCE AND MICROWAVE MEASUREMENT EQUIPMENT	$20K	0.5	4 MONTHS
2.2.2.2	DOSIMETRY SAR MEASUREMENT	$30K	0.5	6 MONTHS
2.2.2.3	CHRONIC EXPOSURE CHAMBER	$40K	1	6 MONTHS

TABLE 21

2.2 EFFECTS ON RABBIT EEG PATTERNS, AS WELL AS CHEMICAL, CYTO-CHEMICAL AND IMMUNOLOGICAL PROPERTIES IN BLOOD

PROTOCOL 2.2.3.0 BIOLOGICAL MEASUREMENTS OF EEG, HEART-RATE, AND PARAMETERS IN BLOOD

- HYPOTHESIS OR TASK: IT IS REPORTED THAT CHRONIC LOW-LEVEL MICROWAVE RADIATION CAN ALTER RABBIT EEG, INDUCE BRADYCARDIA, AFFECT CHEMICAL, CYTO-CHEMICAL AND IMMUNOLOGICAL PROPERTIES IN BLOOD.
- APPROACH: RECORD EEG AND EKG WEEKLY, DRAW BLOOD MONTHLY BEFORE, IN-BETWEEN AND AFTER MICROWAVE IRRADIATION. THE EEG WILL BE RECORDED ON MAGNETIC TAPE AND ANALYZED BY COMPUTER. EYES OF RABBITS WILL BE EXAMINED MONTHLY WITH SLIT LAMP FOR POSSIBLE CATARACT FORMATION. RESULTS ON EXPOSED GROUP WILL BE COMPARED TO CONTROL GROUP.
- INFORMATION TO BE DERIVED: DETERMINE WHAT PHYSIOLOGICAL PARAMETERS CAN BE INFLUENCED BY THE MICROWAVE EXPOSURE.
- EXPERIMENT TIME:

MONTHS TO COMPLETE	18
MAN YEARS	1.5

- COST FOR RESEARCH: $70K
- NEW FACILITIES REQUIRED:

TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
NONE			

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TABLE 22

2.2 EFFECTS ON RABBIT EEG PATTERNS, AS WELL AS CHEMICAL, CYTO-CHEMICAL AND IMMUNOLOGICAL PROPERTIES IN BLOOD

PROTOCOL 2.2.4.0 PATHOLOGICAL EXAMINATION OF ORGANS

- HYPOTHESIS OR TASK: TO DETERMINE WHETHER CHRONIC LOW-LEVEL MICROWAVE RADIATION CAN CAUSE PATHOLOGICAL ALTERATIONS IN ORGANS.
- APPROACH: ONE MONTH AFTER THE TERMINATION OF MICROWAVE RADIATION, ALL THE ANIMALS WILL BE SACRIFICED. ALL PARTS OF THE INTERNAL ORGANS WILL BE EXAMINED MACROSCOPICALLY AND MICROSCOPICALLY. SPLEEN AND LYMPH NODES WILL BE DISECTED OUT FOR THE STUDY ON B CELLS OF THE IMMUNOLOGICAL SYSTEM.
- INFORMATION TO BE DERIVED: DETERMINE THE DEGREE OF TISSUE DAMAGE AT EACH INCIDENT POWER DENSITY.
- EXPERIMENT TIME:

MONTHS TO COMPLETE	1.5
MAN YEARS	0.3

- COST FOR RESEARCH: $8K
- NEW FACILITIES REQUIRED:

TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
NONE			

TABLE 23

2.2 EFFECTS ON RABBIT EEG PATTERNS, AS WELL AS CHEMICAL, CYTO-CHEMICAL AND IMMUNOLOGICAL PROPERTIES IN BLOOD

PROTOCOL 2.2.5.0 REPEAT LOWEST LEVEL EXPERIMENT

- o HYPOTHESIS OR TASK: TO CONFIRM THE EFFECT OBSERVED AT THE LOWEST INCIDENT POWER DENSITY.
- o APPROACH: REPEAT THE SAME EXPERIMENT AT THE LOWEST LEVEL WHEN EFFECTS WERE OBSERVED IN PREVIOUS STUDIES.
- o INFORMATION TO BE DERIVED: THE THRESHOLD INCIDENT POWER DENSITY OF MICROWAVE PHYSIOLOGICAL EFFECTS ON RABBITS WILL BE ESTABLISHED.
- o EXPERIMENT TIME:

MONTHS TO COMPLETE	6
MAN YEARS	1.1

- o COST FOR RESEARCH: $48K
- o NEW FACILITIES REQUIRED:

TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
COMMON WITH 2.2.2.0			

TABLE 24

2.2 EFFECTS ON RABBIT EEG PATTERNS, AS WELL AS CHEMICAL, CYTO-CHEMICAL AND IMMUNOLOGICAL PROPERTIES IN BLOOD

<u>PROTOCOL 2.2.6.0 ANALYSIS AND REPORT FOR 2.2.1.0 THROUGH 2.2.5.0</u>

- <u>HYPOTHESIS OR TASK</u>: PREPARE A FINAL REPORT ON THE THREE-YEAR RESEARCH PROGRAM TO ANSWER THE QUESTION WHAT LEVEL OF CHRONIC LOW-LEVEL RADIATION CAN CAUSE EFFECTS ON RABBIT EEG PATTERNS, AS WELL AS CHEMICAL, CYTO-CHEMICAL AND IMMUNOLOGICAL PROPERTIES IN BLOOD.
- <u>APPROACH</u>: COMPILE AND ANALYZE DATA OBTAINED IN THE EXPERIMENTS. WRITE REPORT.
- <u>INFORMATION TO BE DERIVED</u>: THE RESULTS OF THIS RESEARCH WILL PROVIDE A DATA BASE ON THE LOWEST LEVEL OF MICROWAVE IRRADIATION WHICH CAN CAUSE EFFECTS ON NERVOUS, CARDIOVASCULAR, BIOCHEMICAL AND IMMUNOLOGICAL SYSTEMS IN RABBITS. EXTRAPOLATION TO HUMANS MAY HELP TO PROMULGATE SAFETY STANDARDS ON CHRONIC MICROWAVE EXPOSURE.
- <u>EXPERIMENT TIME</u>:

MONTHS TO COMPLETE	4
MAN YEARS	0.5

- <u>COST FOR RESEARCH</u>: $20K
- <u>NEW FACILITIES REQUIRED</u>:

TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
NONE			

65

2.3 DOES MICROWAVE IRRADIATION ALTER ANY BIOLOGICAL MEMBRANE PERMEABILITY?

66 PROTOCOL 2.3.1.0 EXAMINATION OF BLOOD-BRAIN BARRIER PERMEABILITY ALTERATION BY MICROWAVES

- HYPOTHESIS OR TASK: THE PRELIMINARY EVIDENCE THAT LOW LEVELS OF ACUTE OR CHRONIC IRRADIATION MAY ALTER PERMEABILITY OF THE BLOOD-BRAIN BARRIER REQUIRES AN EFFORT TO CONFIRM OR TO REFUTE THE OBSERVATIONS AT 2.45 GHz.
- APPROACH: TEST NEW BIOLOGICAL AND BIOCHEMICAL METHODOLOGIES TO SELECT APPROPRIATE ANIMAL MODELS TO BE EMPLOYED, AND SPECIFY THE PROTECTIVE HOUSING AND ANIMAL HANDLING PROCEDURES TO AVOID THE STRESS WHICH CAN IMPAIR INTERPRETATION OF THE EXPERIMENTAL DATA. THE MODEL SHALL BE TESTED BY DEMONSTRATING A PENETRATION OF APPROPRIATE TEST SUBSTANCES UNDER CONDITIONS OF KNOWN BLOOD-BRAIN BARRIER ALTERATION.
- INFORMATION TO BE DERIVED: PARALLEL STUDIES TO MEASURE PERMEABILITY OF ERYTHROCYTE AND PERITONEAL MEMBRANES AND THE PLACENTAL BARRIER AS A FUNCTION OF 2.45 GHz MICROWAVE EXPOSURE.
- EXPERIMENT TIME:

MONTHS TO COMPLETE	24
MAN YEARS	3

- COST FOR RESEARCH: $60K
- NEW FACILITIES REQUIRED:

	TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
2.3.1.1	THERMOGRAPHIC AND POWER DENSITY DISTRIBUTION EQUIPMENT	$20K	0.5	6 MONTHS
2.3.1.2	MINIMAL STRESS HOUSING	$40K	1.0	4 MONTHS
2.3.1.3	MINIMAL STRESS IRRADIATION FACILITIES & INSTRUMENTATION	$40K	1.0	6 MONTHS
2.3.1.4	CHAMBER FOR IRRADIATING SINGLE MICE	$40K	1.0	6 MONTHS
2.3.1.5	MICROWAVE MEASUREMENT EQUIPMENT	$20K	0.5	4 MONTHS

TABLE 26

2.3 DOES MICROWAVE IRRADIATION ALTER ANY BIOLOGICAL MEMBRANE PERMEABILITY?

PROTOCOL 2.3.2.0 TEST OF ERYTHROCYTE MEMBRANE LEAKAGE DURING OR FOLLOWING ACUTE OR CHRONIC MICROWAVE IRRADIATION

- HYPOTHESIS OR TASK: TO DETERMINE WHETHER ANY AUTHENTIC MICROWAVE-INDUCED CHANGES OCCUR IN ERYTHROCYTE MEMBRANES. INASMUCH AS PRELIMINARY INFORMATION SUGGESTS THAT MEMBRANE PERMEABILITY MAY BE ALTERED BY MICROWAVE IRRADIATION WITH POSSIBLE PATHOLOGICAL CONSEQUENCES THE ERYTHROCYTE MEMBRANE CONSTITUTES A WELL-ESTABLISHED AND USEFUL EXPERIMENTAL MODEL FOR TESTING SUCH OBSERVATIONS. THE FIRST TASK WILL BE TO DETERMINE WHETHER PERMEABILITY ALTERATIONS CAN BE DEMONSTRATED UNDER CAREFULLY CONTROLLED EXPERIMENTAL CONDITIONS.
- APPROACH: PRIOR TO THE IN VIVO IRRADIATION OF ANIMALS, THE POSSIBILITY FOR DEMONSTRATING EFFECTS IN VITRO WILL BE EXAMINED. IF MEMBRANE PERMEABILITY ALTERATIONS CAN BE PRODUCED UNDER IN VITRO CIRCUMSTANCES, THE MINIMAL THRESHOLD WILL BE ESTABLISHED. THIS WILL PROVIDE GUIDANCE FOR ESTABLISHING THE MW POWER DENSITY IN VIVO.
- INFORMATION TO BE DERIVED: ALTERATIONS OF PERMEABILITY (IF ANY), DETERMINED BY AN INCREASED LEAKAGE OF ESTABLISHED COMPONENTS ASSOCIATED WITH ERYTHROCYTES SUCH AS HEMOGLOBIN, OR ENZYMES KNOWN TO BE HIGHLY SPECIFIC FOR RED CELLS, SUCH AS GLUCOSE-6-PHOSPHATE DEHYDROGENASE, WILL BE DETERMINED AND THRESHOLD MICROWAVE POWER DENSITIES AT 2450 MHz WILL BE ESTABLISHED.
- EXPERIMENT TIME:
  - MONTHS TO COMPLETE 24
  - MAN YEARS 2
- COST FOR RESEARCH: $40K
- NEW FACILITIES REQUIRED:

TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
COMMON WITH 2.3.1.0			

TABLE 27

68 2.3 DOES MICROWAVE IRRADIATION ALTER ANY BIOLOGICAL MEMBRANE PERMEABILITY?

PROTOCOL 2.3.3.0 MEASUREMENT OF PERITONEAL MEMBRANE PERMEABILITY DURING AND FOLLOWING MICROWAVE IRRADIATION

- HYPOTHESIS OR TASK: TO DETERMINE WHETHER MICROWAVE-INDUCED CHANGES OCCUR IN THE PERITONEAL MEMBRANE PERMEABILITY WHEN TESTED BY A VARIETY OF SPECIALLY SELECTED MATERIALS.
- APPROACH: VARIOUS ENTITIES, EASY TO IDENTIFY, WILL BE EMPLOYED IN ORDER TO MEASURE WITH ACCURACY ANY ALTERATIONS THAT MAY OCCUR IN THE MIGRATION OF SUBSTANCES OF VARIOUS MOLECULAR WEIGHTS AND MACROMOLECULAR SIZES. TEST SUBSTANCES WILL INCLUDE CANCER CELLS, ENZYMES, AND A BENIGN VIRUS, ALL OF WHICH CAN BE MEASURED WITH PRECISION.
- INFORMATION TO BE DERIVED: QUANTITATIVE ALTERATIONS (IF ANY) IN THE TRANSPORT OF A WIDE VARIETY OF TEST SUBSTANCES THROUGH THE PERITONEAL MEMBRANES AS A FUNCTION OF VARIOUS POWER DENSITY LEVELS AND DURATION OF IRRADIATION. POWER DENSITY THRESHOLDS WILL BE ESTABLISHED FOR ANY MEASURABLE ALTERATIONS IN SUCH MEMBRANE PERMEABILITY.
- EXPERIMENT TIME:

MONTHS TO COMPLETE	24
MAN YEARS	2

- COST FOR RESEARCH: $40K
- NEW FACILITIES REQUIRED:

TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
COMMON WITH 2.3.1.0			

TABLE 28

2.3 DOES MICROWAVE IRRADIATION ALTER ANY BIOLOGICAL MEMBRANE PERMEABILITY?

PROTOCOL 2.3.4.0 MEASUREMENT OF PLACENTAL BARRIER PERMEABILITY DURING AND FOLLOWING MICROWAVE IRRADIATION

- HYPOTHESIS OR TASK: ATTEMPT TO CONFIRM PRELIMINARY OBSERVATIONS THAT MICROWAVE IRRADIATION IS CAPABLE OF INDUCING ALTERATIONS IN BIOLOGICAL MEMBRANE PERMEABILITY AT 2.45 GHz.
- APPROACH: THE BENIGN LDH-ELEVATING VIRUS HAS NO OVERT PATHOLOGICAL EFFECTS ON EITHER HOST OR FETUS. UNDER CERTAIN EXPERIMENTAL CIRCUMSTANCES THIS VIRUS IS CAPABLE OF PENETRATING THE PLACENTAL BARRIER AND INFECTING THE FETUSES. SUCH PENETRATION CAN BE ESTABLISHED BY ASSAYING THE NEWBORN ANIMALS. SUCH VIRAL PASSAGE OF THE PLACENTAL BARRIER IS A SENSITIVE FUNCTION OF PERMEABILITY: ANY ALTERATIONS IN THE BARRIER TO SUCH VIRUS PASSAGE SHOULD BE A USEFUL INDICATOR OF MEMBRANE PERMEABILITY CHANGE. OTHER STANDARD MEANS FOR MEASURING PLACENTAL BARRIER PERMEABILITY WILL ALSO BE EMPLOYED.
- INFORMATION TO BE DERIVED: QUANTITATIVE ALTERATIONS (IF ANY) IN THE PERMEABILITY OF PLACENTAL BARRIERS WILL BE ESTABLISHED AS A FUNCTION OF 2.45GHz MICROWAVE IRRADIATION POWER DENSITY. THE THRESHOLD DOSE WILL BE ESTABLISHED AS A FUNCTION OF TIME OF MW EXPOSURE.
- EXPERIMENT TIME:

MONTHS TO COMPLETE	24
MAN YEARS	2

- COST FOR RESEARCH: $40K
- NEW FACILITIES REQUIRED:

TYPE	COST $	MAN YEARS	TIME TO ACQUIRE

COMMON WITH

2.3.1.0

TABLE 29

70 2.3 DOES MICROWAVE IRRADIATION ALTER ANY BIOLOGICAL MEMBRANE PERMEABILITY?

PROTOCOL 2.3.5.0 EXPERIMENTAL REPETITION OF CRITICAL OR PROVOCATIVE EXPERIMENTAL FINDINGS

- HYPOTHESIS OR TASK: TO REPEAT THOSE SELECTED EXPERIMENTS WHICH WILL PROVIDE CONFIRMATION AND AUTHENTICITY TO MICROWAVE THRESHOLD VALUES.
- APPROACH: REPEAT EXPERIMENTS EXACTLY AS ORIGINALLY DESIGNED, OR BY THE INTRODUCTION OF NEW MODULATIONS WHICH MAY BE REQUIRED BY EARLIER RESULTS.
- INFORMATION TO BE DERIVED: CONFIRMATION OF THRESHOLD MW VALUES IN RESPECT TO SPECIFIC PHYSIOLOGICAL PARAMETERS.
- EXPERIMENT TIME:

MONTHS TO COMPLETE	10
MAN YEARS	2

- COST FOR RESEARCH: $20K
- NEW FACILITIES REQUIRED:

TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
COMMON WITH 2.3.1.0			

TABLE 30

2.3 DOES MICROWAVE IRRADIATION ALTER ANY BIOLOGICAL MEMBRANE PERMEABILITY?

PROTOCOL 2.3.6.0 ANALYSIS AND REPORTS ON MEMBRANE PERMEABILITY

- o HYPOTHESIS OR TASK: TO PREPARE FINAL REPORTS AND MANUSCRIPTS FOR PUBLICATION.
- o APPROACH: ANALYZE ACCUMULATED DATA BY APPROPRIATE STATISTICAL ANALYSIS, PREPARE TABLES, CHARTS, AND FIGURES DEPICTING THE ESSENTIAL FINDINGS OF THE STUDY.
- o INFORMATION TO BE DERIVED: ESTABLISH DEFINITIVE INFORMATION ON THE BIOLOGICAL EFFECTS OF 2450 MHz MICROWAVES, AND THE DETERMINATION OF POWER DENSITY THRESHOLDS.
- o EXPERIMENT TIME:

MONTHS TO COMPLETE	6
MAN YEARS	0.5

- o COST FOR RESEARCH: $15K
- o NEW FACILITIES REQUIRED:

TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
NONE			

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TABLE 31

2.4 WHAT ARE THE EFFECTS OF 2.45 GHz MICROWAVE IRRADIATION ON BEHAVIOR?

PROTOCOL 2.4.1.0 BEHAVIORAL TERATOLOGY

- o HYPOTHESIS OR TASK: DETERMINE THE EFFECTS OF CHRONIC FETAL EXPOSURE TO MICROWAVE ON SUBSEQUENT ADULT BEHAVIOR.
- o APPROACH: EXPOSE PREGNANT RATS FOR AS MUCH OF THE GESTATIONAL PERIOD AS POSSIBLE TO EXAMINE THE WORST POSSIBLE CASE FOR DURATION OF EXPOSURE. THE INCIDENT POWER DENSITY WILL BE 1 mW/cm^2 FOR 2450 MHz MICROWAVES. SUBSEQUENT STUDIES WILL DEPEND ON THE OUTCOME OF THE FIRST EXPOSURE AT 1 mW/cm^2.
- o INFORMATION TO BE DERIVED: THE EFFECT OF THE IN-UTERO EXPOSURE ON SUBSEQUENT ADULT BEHAVIOR, E.G., SHUTTLEBOX AVOIDANCE, APPETITIVE CONDITIONING, ETC., WILL BE DETERMINED.
- o EXPERIMENT TIME:

MONTHS TO COMPLETE	8
MAN YEARS	1

- o COST FOR RESEARCH: $35K
- o NEW FACILITIES REQUIRED:

	TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
2.4.1.1	POWER SOURCE AND MW MEASUREMENT	$20K	0.5	4 MONTHS
2.4.1.2	DOSIMETRY, SAR	$30K	0.5	6 MONTHS
2.4.1.3	CHRONIC EXPOSURE CHAMBER	$40K	1	6 MONTHS
2.4.1.4	BEHAVIOR TESTING AND LOGIC SYSTEM	$40K	1	8 MONTHS

TABLE 32

2.4 WHAT ARE THE EFFECTS OF 2.45 GHz MICROWAVE IRRADIATION ON BEHAVIOR?

PROTOCOL 2.4.2.0 LEARNING AND MEMORY

- o HYPOTHESIS OR TASK: DETERMINE EFFECTS OF CHRONIC EXPOSURE TO MICROWAVES ON LEARNING ABILITY AND MEMORY CONSOLIDATION.
- o APPROACH: RATS WILL BE TRAINED TO MAKE A SERIES OF SEQUENTIAL DISCRIMINATIONS IN AN OPERANT CHAMBER EQUIPPED WITH 4 MANIPULANDA. THIS FORM OF TRAINING PROVIDES A SERIES OF RELATED PROBLEMS SO THAT THE RODENT ESSENTIALLY ACQUIRES A "LEARNING SET". WHILE NOT PERFORMING IN THE TASK, THE RODENTS WILL BE EXPOSED TO 2450 MHz MICROWAVES AT 1 mW/cm^2.
- o INFORMATION TO BE DERIVED: THE TASK SELECTED ALLOWS FOR DETERMINING MICROWAVE EFFECTS ON DAILY ACQUISITION SESSIONS (MINI LEARNING CURVE) AS WELL AS ON THE RETENTION OF PRIOR DAYS' TRAINING (THE LEARNING SET ACQUISITION).
- o EXPERIMENT TIME:

MONTHS TO COMPLETE	6
MAN YEARS	1

- o COST FOR RESEARCH $40K
- o NEW FACILITIES REQUIRED:

TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
COMMON WITH 2.4.1.0			

TABLE 33

2.4 WHAT ARE THE EFFECTS OF 2.45 GH_Z MICROWAVE IRRADIATION ON BEHAVIOR?

PROTOCOL 2.4.3.0 MOTIVATIONAL STATES-STRESS/AROUSAL AND ATTENTION/VIGILANCE

- HYPOTHESIS OR TASK: DETERMINE WHETHER CHRONIC LOW-LEVEL MICROWAVE RADIATION EXPOSURE EFFECTS A VARIETY OF MOTIVATIONAL STATES IN THE RODENT.
- APPROACH: FOLLOWING CHRONIC EXPOSURE, VARIOUS GROUPS OF ANIMALS SHOULD BE TESTED UNDER CONDITIONS OF HIGH STRESS/AROUSAL SUCH AS IN THE ACQUISITION OF A SHUTTLEBOX AVOIDANCE RESPONSE. OTHER GROUPS SHOULD BE TESTED IN A NON-AVERSIVE TASK REQUIRING ATTENTION/VIGILANCE - SUCH AS A CROSS-MODAL TRANSFER IN A TIME-TRACKING TASK MAINTAINED BY POSITIVE REINFORCEMENT.
- INFORMATION TO BE DERIVED: THE EFFECTS OF CHRONIC LOW-LEVEL MICROWAVE RADIATION (2450 MH_Z AT 1 mW/cm^2) ON THE ANIMALS' AROUSAL STATE WILL BE DETERMINED.
- EXPERIMENT TIME:

MONTHS TO COMPLETE	6
MAN YEARS	1

- COST FOR RESEARCH: $40K
- NEW FACILITIES REQUIRED:

TYPE	COST $	MAN YEARS	TIME TO ACQUIRE

COMMON WITH
2.4.1.0

TABLE 34

2.4 WHAT ARE THE EFFECTS OF 2.45 GHz MICROWAVE IRRADIATION ON BEHAVIOR?

PROTOCOL 2.4.4.0 SCHEDULE CONTROLLED BEHAVIOR

- o HYPOTHESIS OR TASK: DETERMINE WHETHER CHRONIC LOW-LEVEL MICROWAVE RADIATION EXPOSURE EFFECTS BEHAVIOR UNDER THE CONTROL OF COMPLEX REINFORCEMENT SCHEDULING.
- o APPROACH: A NUMBER OF CONCURRENT OR TANDEM SCHEDULES THAT PRODUCE UNIQUE RESPONSE DISTRIBUTIONS SHOULD BE EXAMINED. IN EACH CASE IT SHOULD BE DETERMINED WHETHER THE CHRONIC MICROWAVE EXPOSURE AFFECTS THE RATE OR DISTRIBUTION OF RESPONSES COMMON TO THE SCHEDULE UNDER STUDY.
- o INFORMATION TO BE DERIVED: THE EFFECTS OF CHRONIC LOW-LEVEL MICROWAVE RADIATION (2450 MHz AT 1 mW/cm^2) ON THE ANIMALS BEHAVIOR WILL BE DETERMINED.
- o EXPERIMENT TIME:

MONTHS TO COMPLETE	6
MAN YEARS	1

- o COST FOR RESEARCH: $40K
- o NEW FACILITIES REQUIRED:

TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
COMMON WITH 2.4.1.0			

75

TABLE 35

2.4 WHAT ARE THE EFFECTS OF 2.45 GHz MICROWAVE IRRADIATION ON BEHAVIOR?

PROTOCOL 2.4.5.0 ANALYSIS AND REPORT ON THE MICROWAVE EFFECTS ON BEHAVIOR

- HYPOTHESIS OR TASK: PREPARE A FINAL REPORT ON THE THREE YEAR RESEARCH PROGRAM TO RESOLVE WHAT EFFECTS ON BEHAVIOR, IF ANY, CAN BE ATTRIBUTED TO THE CHRONIC LOW-LEVEL MICROWAVE EXPOSURES.
- APPROACH: COMPILE AND ANALYZE DATA FROM THE EXPERIMENTS.
- INFORMATION TO BE DERIVED: DETERMINATION AND QUANTITATION OF SPECIFIC EFFECTS COUPLED WITH SUFFICIENT INTERPRETATION TO EXTRAPOLATE TO A REAL TIME SITUATION VIZ., WITH ECOLOGICAL VALIDITY.
- EXPERIMENT TIME:

MONTHS TO COMPLETE	4
MAN YEARS	1

- COST FOR RESEARCH: $30K
- NEW FACILITIES REQUIRED:

TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
NONE			

TABLE 36

2.5 WHAT ARE THE EFFECTS OF 2.45 GHz MICROWAVE IRRADIATION ON REPRODUCTION?

PROTOCOL 2.5.1.0 MULTIPLE GENERATION EXPOSURE

- o HYPOTHESIS OR TASK: EXPOSE MICE OR RATS CHRONICALLY TO MICROWAVE IRRADIATION FOR SEVERAL GENERATIONS TO STUDY THE EFFECTS ON REPRODUCTION.
- o APPROACH: BOTH MALE AND FEMALE MICE OR RATS WILL BE HOUSED TOGETHER AND EXPOSED TO 1 mW/cm^2 2450 MHz MICROWAVES FOR SEVERAL GENERATIONS.
- o INFORMATION TO BE DERIVED: BIOLOGICAL MEASUREMENTS ON REPRODUCTION ON THE EXPOSED ANIMALS CAN BE MADE.
- o EXPERIMENT TIME:

MONTHS TO COMPLETE	24
MAN YEARS	1

- o COST FOR RESEARCH: $35K
- o NEW FACILITIES REQUIRED:

	TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
2.5.1.1	POWER SOURCE AND MICROWAVE MEASUREMENT EQUIPMENT	$20K	0.5	4 MONTHS
2.5.1.2	DOSIMETRY, SAR MEASUREMENT	$30K	0.5	6 MONTHS
2.5.1.3	CHRONIC EXPOSURE CHAMBER	$40K	1	6 MONTHS

TABLE 37

2.5 WHAT ARE THE EFFECTS OF 2.45 GHz MICROWAVE IRRADIATION ON REPRODUCTION?

PROTOCOL 2.5.2.0 TERATOLOGY

- o HYPOTHESIS OR TASK: TO DETERMINE ANY TERATOLOGICAL EFFECTS OF MICROWAVE IRRADIATION.
- o APPROACH: SOME OF THE EXPOSED DAMS WILL HAVE PUPS TAKEN ON THE 19TH DAY OF GESTATION FOR POSSIBLE TERATOGENIC EFFECTS EXAMINATION WHILE OTHERS WILL BE ALLOWED TO TERM.
- o INFORMATION TO BE DERIVED: PROVIDE DATA ON TERATOLOGIC EFFECTS OF CHRONIC LOW-LEVEL MICROWAVE IRRADIATION.
- o EXPERIMENT TIME:

MONTHS TO COMPLETE	24
MAN YEARS	1

- o COST FOR RESEARCH: $35K
- o NEW FACILITIES REQUIRED:

TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
NONE			

TABLE 38

2.5 WHAT ARE THE EFFECTS OF 2.45 GHz MICROWAVE IRRADIATION ON REPRODUCTION?

PROTOCOL 2.5.3.0 FERTILITY AND FECUNDITY

- o HYPOTHESIS OR TASK: TO DETERMINE THE FERTILITY AND FECUNDITY OF MICE OR RATS UNDER CHRONIC LOW-LEVEL MICROWAVE IRRADIATION.
- o APPROACH: NUMBER OF PREGNANCY AND SIZE OF LITTERS WILL BE COUNTED.
- o INFORMATION TO BE DERIVED: THE EFFECTS OF CHRONIC LOW-LEVEL MICROWAVE IRRADIATION ON THE FERTILITY AND FECUNDITY OF ANIMALS WILL BE ESTABLISHED.
- o EXPERIMENT TIME:

MONTHS TO COMPLETE	24
MAN YEARS	1

- o COST FOR RESEARCH: $35K
- o NEW FACILITIES REQUIRED:

TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
NONE			

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TABLE 39

2.5 WHAT ARE THE EFFECTS OF 2.45 GHz MICROWAVE IRRADIATION ON REPRODUCTION?

PROTOCOL 2.5.4.0 GROWTH AND DEVELOPMENT

- o HYPOTHESIS OR TASK: TO DETERMINE WHETHER GROWTH DEVELOPMENT AND GENERAL HEALTH OF OFFSPRING ARE AFFECTED OVER A MULTI-GENERATIONAL EXPOSURE.
- o APPROACH: THE OFFSPRING WILL BE EXAMINED FOR DEVELOPMENTAL MILESTONES, RATE OF GROWTH AND DEVELOPMENT INCLUDING A COMPLETE NEUROLOGIC PROFILE.
- o INFORMATION TO BE DERIVED: PROVIDE DATA ON GROWTH AND DEVELOPMENT OF ANIMALS EXPOSED TO MICROWAVES MULTI-GENERATIONALLY.
- o EXPERIMENT TIME:

MONTHS TO COMPLETE	24
MAN YEARS	1

- o COST FOR RESEARCH: $35K
- o NEW FACILITIES REQUIRED:

TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
NONE			

TABLE 40

2.5 WHAT ARE THE EFFECTS OF 2.45 GHz MICROWAVE IRRADIATION ON REPRODUCTION?

PROTOCOL 2.5.5.0 ANALYSIS AND REPORT

- o HYPOTHESIS OR TASK: FROM THE RESULTS ON TERATOLOGY, FERTILITY, FECUNDITY, GROWTH AND DEVELOPMENT, A REPORT OF THE MULTI-GENERATION MICROWAVE IRRADIATION EFFECTS ON REPRODUCTION WILL BE PREPARED.
- o APPROACH: PROVIDE STATISTICAL DATA FOR THE REPORT AND ANALYZE THE SIGNIFICANCE OF THE DATA USING DIFFERENT STATISTICAL CALCULATIONS. WRITE REPORT IN FINAL FORM.
- o INFORMATION TO BE DERIVED: TO ANSWER THE QUESTION WHETHER THE CHRONIC LOW-LEVEL MICROWAVE IRRADIATION CAN EFFECT THE REPRODUCTION.
- o EXPERIMENT TIME:

MONTHS TO COMPLETE	6
MAN YEARS	0.5

- o COST FOR RESEARCH: $20K
- o NEW FACILITIES REQUIRED:

TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
NONE			

MILESTONE AND FUNDING SUMMARY

TABLE 41

MILESTONE AND FUNDING SUMMARY

	PHASE A YEAR				COST $K		
	0	1	2	3	Exper.	Facil.	Question
2.1.0.0 Immunological System				∇	--	---	375
2.1.1.0 Chronic Exposure		∇	∇	∇	60	160	
2.1.2.0 Biological Measurement		∇	∇	∇	120	---	
2.1.3.0 Repeat Experiment				∇	20	---	
2.1.4.0 Analysis and Report				∇	15	---	
2.2.0.0 Rabbit Exposure				∇	--	---	316
2.2.1.0 Carbon Electrode		∇			15	---	
2.2.2.0 Chronic Exposure		∇	∇	∇	65	90	
2.2.3.0 Biological Measurement		∇	∇	∇	70	---	
[illegible] Pathological Measurement		∇	∇	∇	8	---	
[illegible] Repeat Experiment					48	--	
[illegible] Analysis and Report					20	---	

TABLE 41. - Continued

	PHASE A YEAR				COST $K		
	0	1	2	3	Exper.	Facil.	Question
2.3.0.0 Cell Membrane				▽	--	---	375
2.3.1.0 Blood Brain Barrier		▽	▽		60	160	
2.3.2.0 Red Blood Cell		▽	▽		40	---	
2.3.3.0 Peritoneal Membrane		▽	▽		40	---	
2.3.4.0 Placental Barrier		▽	▽		40	---	
2.3.5.0 Repeat Experiment				▽	20	---	
2.3.6.0 Analysis and Report				▽	15	---	
2.4.0.0 Behavior				▽	--	---	355
2.4.1.0 Behavior Teratology		▽	▽		35	170	
2.4.2.0 Learning and Memory			▽		40	---	
2.4.3.0 Behavioral Status			▽	▽	40	---	
2.4.4.0 Schedule Controlled				▽	40	---	
2.4.5.0 Analysis Report				▽	30	---	

TABLE 41. - Concluded

	PHASE A YEAR				COST $K		
	0	1	2	3	Exper.	Facil.	Question
2.5.0.0 Reproduction				∇	--	---	270
2.5.1.0 Multigeneration Exposure		∇	∇	∇	35	110	
2.5.2.0 Teratology		∇	∇	∇	35	---	
2.5.3.0 Fertility/Fecundity		∇	∇	∇	35	---	
2.5.4.0 Growth Development		∇	∇	∇	35	---	
2.5.5.0 Analysis and Report				∇	20	---	

PILOT EXPERIMENTATION

A pilot study was conducted to answer some of the questions relating to chronic exposure of animals to microwave fields. Chronic exposure of a large population of animals over long durations of time under normal feeding and watering conditions required techniques that are difficult to implement with conventional facilities used for acute exposures. The study successfully completed the development and testing of a system of miniature anechoic chambers for chronic exposure of rodents to plane wave 2.45 GHz microwave fields. Each animal is supplied with food and water by a method designed to eliminate undesirable field perturbations. Measurements of the field patterns in each chamber, corresponding closely to those made in large anechoic chambers, indicate that a power density of .169 mW/cm^2 per watt input can be provided in the chamber, producing peak SAR levels of 0.37 W/kg in exposed bodies of sacrificed rats. Additional measurements are needed to quantify SAR levels in larger animals such as rabbits. It is important that the proposed work be carried out by research groups that have or can acquire the necessary resources for providing the proper controlled conditions for microwave exposure dosimetry and the laboratory environment. It is also essential that each research team include microwave engineers or physicists experienced in the design and use of microwave exposure systems, as well as life scientists specializing in the biological systems under investigation in order to minimize artifacts in the research results.

V. BIOBEHAVIORAL EFFECTS OF CW 2.45 GHz MICROWAVE ILLUMINATION ON BIRDS*

SIGNIFICANCE OF CATEGORY

Birds are the most mobile of animals and can be expected to fly in and out, or migrate through, the rectenna site. It is the adaptations necessary for flight which may make the bird vulnerable to microwave illumination. Similar problems can be assumed for bats because the cost of flight applies to them as well as to birds. A bird in flight travels through a medium which provides no buoyancy, so it must work not only to move forward, but to remain airborne, sometimes for long periods of time. For minimum weight, strong efficient muscles are attached to strong, but hollow, bones; the digestive system is organized to quickly process and store fat which is light for the energy that it provides. Its body is covered with feathers which provide superb insulation and are light and hollow. Yet, despite these adaptations, the energy cost of flight to the bird is high, and is apparent from the bird's body temperature increase during flight. For example, the resting body temperature of a passerine, the common house sparrow (*Passer domesticus*), is 43.5° C.. The upper critical body temperature for passerines is 44.8° C., and upper lethal temperature is 46.8° C. (14). During flight, the body temperature can increase by 1°- 2.5° C., dependent upon such factors as velocity of flight and wind conditions. Since this increase in body temperature can be very close to the bird's upper critical limit, a determination of the added increments of heat from microwave absorption becomes a high priority task to determine how vulnerable birds may become in the rectenna field. Relevant parameters include bird size, species, speed of flight, and orientation of flight in and through the microwave field.

First priority has been given to investigations of the biobehavioral effects of microwave illumination and the possible lethal effects as related to the animal's size, species, and

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*Abstracted from the Final Report for Ames Research Center, NASA Contract NAS2-9555 "2450 MHz Microwave Absorption in Large and Small Animals and Its Biobehavioral Effects on Birds and Reptiles", Om P. Gandhi, H. Clarke Nielson, James L. Lords, John A. D'Andrea, Orlando Cuellar, and Mark J. Hagmann, University of Utah, February 2, 1978

physiological state, as well as to the environmental conditions such as altitude, ambient temperature, and relative humidity that exist at the time of exposure to microwave illumination. A guide for experimentation can be achieved through computer modeling of birds and their energy costs at rest and feeding, and while landing, taking off, and in flight, in the microwave field at different orientations, and therefore, different specific absorption rates. In the model, the energy expended by the bird can be added to the estimated energy that the bird will absorb from the microwave field. These estimates will then be converted to body temperature data. Estimates of possibly lethal thermal effects can be made for all birds as a function of their size, species, rate of flight, and environmental conditions. These values and their predicted consequences can then be empirically verified in selected species before final conclusions about consequences of flight in the rectenna field are made.

PRIORITIZED LIST OF QUESTIONS

Priorities could change drastically as information is gained from experiments. The first question is obviously the most important. If computer modeling of flight through the beam predicts problems for a large number of species, and if most of those predictions are verified, the next most important question would be whether the birds can detect the field and avoid it. If the birds are able to detect and escape the microwave field, the stress-relaxation properties of their collagens still have to be checked. Collagens are important because body temperatures above normal change the molecular structure of collagens, and alter their stress-relaxation properties. Thus, the birds could have flight tendons that have stretched so that the muscles can no longer do their job efficiently.

The last experiments under this question ask whether it will interfere with the migratory flights when cues for navigation are limited. Providing the microwave field is not lethal, debilitating, detected, or does not interfere with the birds' ability to get about in the world, the fourth set of questions will determine if they will be attracted to the field during cold weather to keep warm. If so, this could interfere with power reception and with the migration of some species since migration is the birds' way of keeping warm. The fifth set of experiments deals with the problems that might be imposed by the types of birds that live in or near the rectenna site. If the birds should be strongly attracted to the microwave field, then question five could assume much greater importance because of the possible systems impact.

1. BIRD THERMAL STRESS: FLIGHT, FOOD INTAKE, AND MICROWAVES

The first priority task is to make a computer model of the body temperature of birds, and empirically test its predictions at rest or flying in a CW 2.45 GHz field at 25 mW/cm^2 as a function of the bird's characteristics (size, speed of flight, species, etc.), the ambient conditions (altitude, temperature, etc.), and microwave field characteristics (bird's flight with variations of body orientations--with respect to the E and H fields) and perturbations from the wing beat and from other birds or flocks in the field. The bird and ambient conditions will be derived using the equation of Tucker (15) and the net gain in body temperature from the microwave field will be

derived from the studies of Gandhi (2,3) and adapted from his recent calculations with multiple animals in the field.

2. BIRD THERMAL STRESS: ALTERATIONS OF PROPERTIES OF COLLAGEN IN FLIGHT TENDONS AND HEART

Collagen is one of the most abundant and widespread proteins in the animal kingdom. It is one of the basic fibrous constituents of tendon, skin, cartilage, and bone. It is an extracellular protein and once formed is metabolically stable in most sites, which is in contrast to other body proteins which show a continuous turn-over of molecules.

Rigby and Robinson (16) have shown that the melting point of the molecular collagen of both homeothermic and poikilothermic animals correlates well with the upper limit of their range of preferred temperatures, that is, the range of temperatures the animal will voluntarily tolerate in the natural environment.

If body temperatures are abnormally high, such as may be the case with microwave absorption combined with the added heat stress of flight and food intake, structural transitions may take place in tendons with serious consequences. The bird may lose the ability of the fine control necessary for landings, takeoffs, and even the capture of prey; or it may lose the ability of flight altogether.

This program outlines a detailed analysis of collagen alterations in birds under a variety of conditions. This approach will provide information on:

a. Whether the flight tendons of birds will be sufficiently altered to impair the fine coordinated flight movements that birds must have to catch prey or avoid predators.

b. Whether possible alteration in tendon will change the efficiency of muscle and interfere with long sustained migratory flights.

3. STIMULUS EFFECTS DURING FLIGHT: AVOIDANCE, INTERFERENCE, OR INTERACTION WITH PHYSIOLOGICAL STATES

Will the SPS microwave field provide sensory cues that may cause the bird to avoid such fields, or disrupt the bird's

ability to navigate, or interact with altered physiological states of the bird that may disrupt migratory behavior?

The impact of the SPS rectenna site on bird migratory behavior is a difficult area to study. Three experimental approaches are outlined:

The first experiments concern the bird in flight and its ability to detect the microwave field. Evidence by King, et al. (17), indicates that the laboratory rat can detect rather low levels of microwave radiation. Scant data, however, exists concerning such responses of the avian species in flight to the microwave field.

The second experiments concern the birds' navigation ability and, perhaps, subsequent migration ability after encountering the microwave field.

The third series of experiments concern the birds' ability to fly successfully through the microwave field after previously enduring a sustained microwave flight. Birds after a long migratory flight are in a much different physiological state than when the flight begins. Dehydration and loss of body fat may account for body weight changes of 35 to 40 percent. Can the bird detect and escape microwave fields when in such a physiological state?

These tasks and the information they can provide will be of utmost concern to the SPS concept. Disruption of major flyways of migrating birds would be difficult ecological problem to handle.

4. ATTRACTION TO OR AVOIDANCE OF THE RECTENNA SITE: DIFFERENT AMBIENT TEMPERATURES

The task is to determine whether ground-living and migratory species will avoid the rectenna site during warm ambient temperatures or are attracted at low ambient temperatures.

Morton (18), and Hamilton and Hepner (19), have exposed birds to radiant solar energy or artificial radiation and have demonstrated that birds ate less food. Presumably, they can to some extent exchange solar energy for food. To investigate the extent that birds will interchange energy at CW 2.45 GHz for food at low ambient temperatures, birds of both ground-living and migratory species would be allowed to seek or avoid a high-level (25 mW/cm^2) CW 2.45 GHz field with ambient

temperatures ranging from -10° C. to $+30^{\circ}$ C. and with the food supply varying from plentiful to sparse. The experimentation is to determine the likelihood that both ground-living bird species and migratory species will seek the microwave field and absorb microwave radiation during the winter season when it is cold and food is scarce.

5. LIVING IN THE RECTENNA SITE: EFFECTS ON REPRODUCTION AND FLIGHT PATTERNS

The last objective is to examine birds which are living in the rectenna site as it relates to effects on reproduction and flight patterns. The approach should be:

a. Different groups of paired pheasants or quail will be flown daily for short durations with and without microwave fields in a wind tunnel. The separate groups will be maintained with and without low-level microwave fields. The duration of sustained flight as well as reproductive behavior will be determined.

b. Ring doves will be paired and maintained in a low-level microwave field. Reproductive behavior such as courtship, mating, nesting, and care of squabs will be studied. Hormonal systems that maintain this behavior can be studied if biobehavioral effects are observed.

PLANNING CHARTS

3.1 BIRD THERMAL STRESS FLIGHT FOOD INTAKE AND MICROWAVES

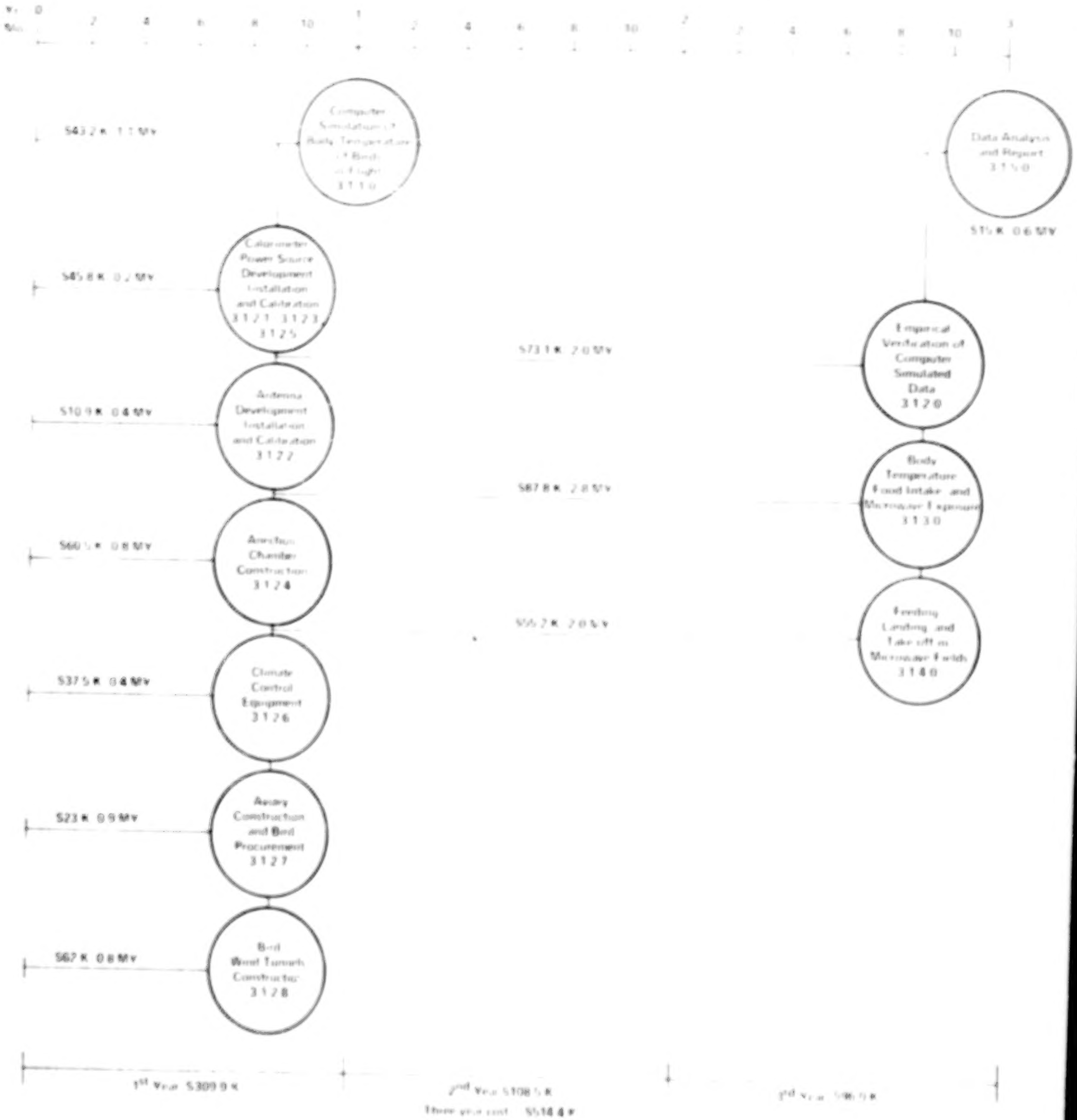

Figure 9

3.2 BIRD THERMAL STRESS: ALTERATIONS OF COLLAGENS

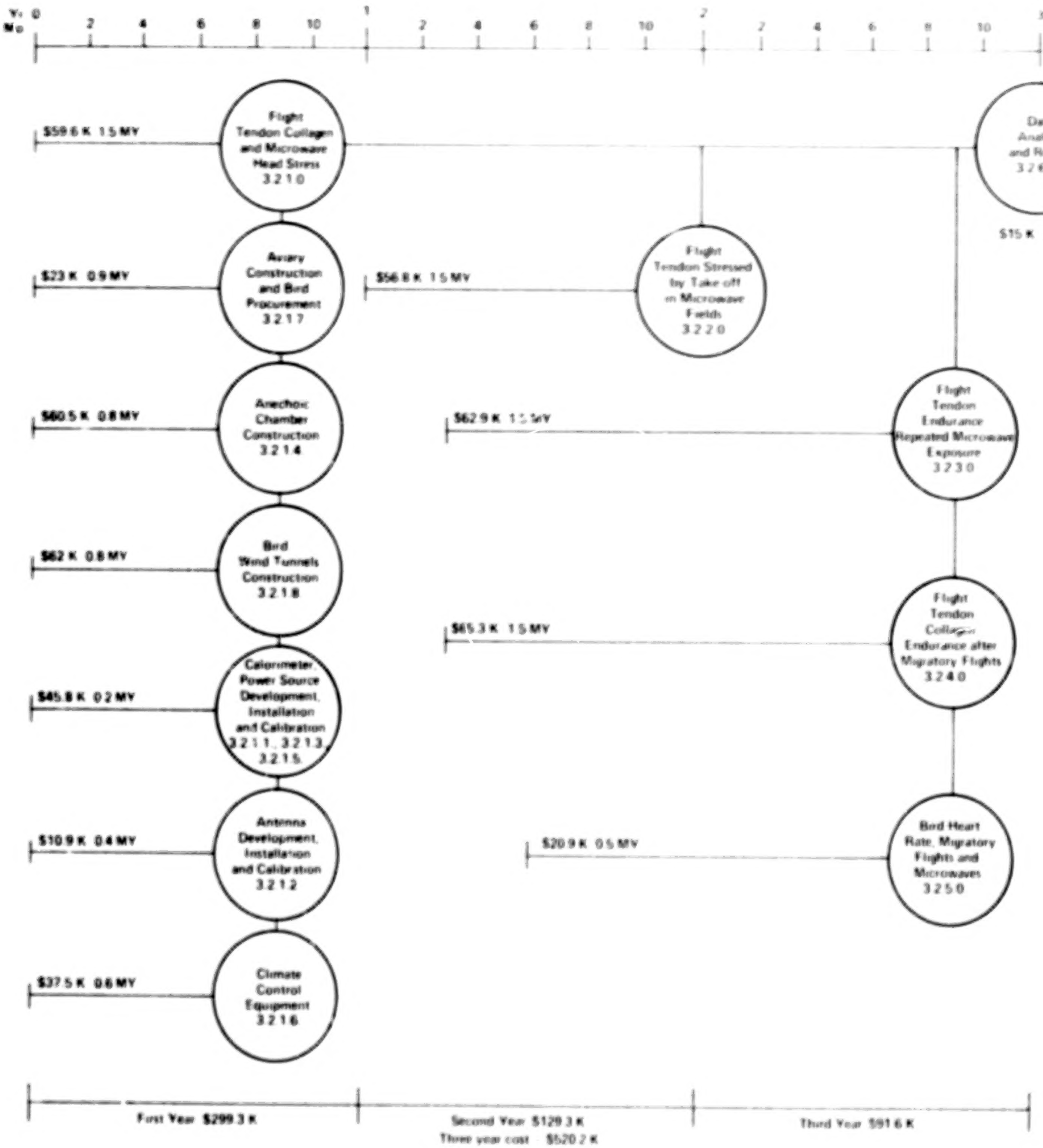

Figure 10

3 3 STIMULUS EFFECTS DURING FLIGHT

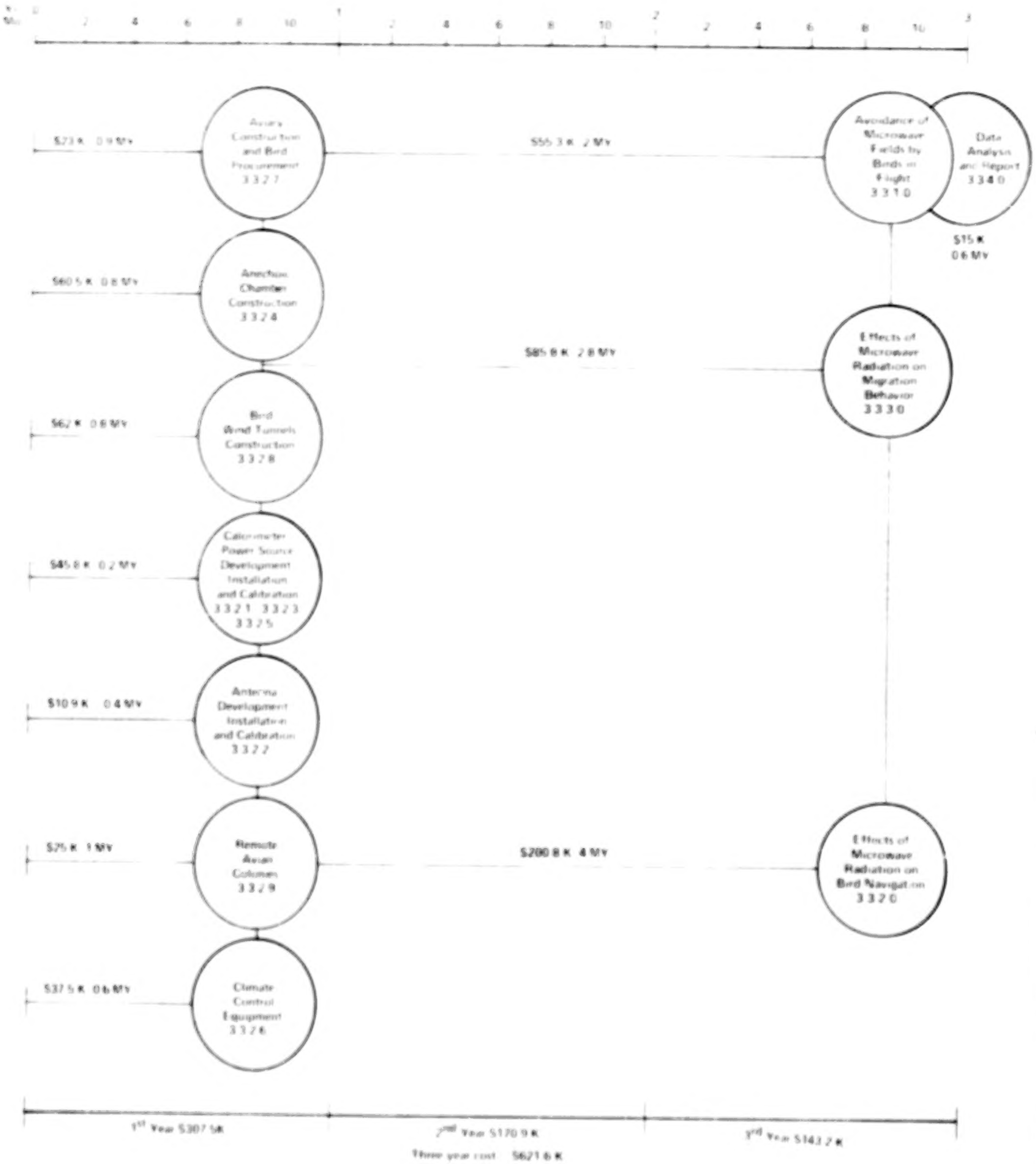

Figure 11

3.4 ATTRACTION/AVOIDANCE OF RECTENNA SITE

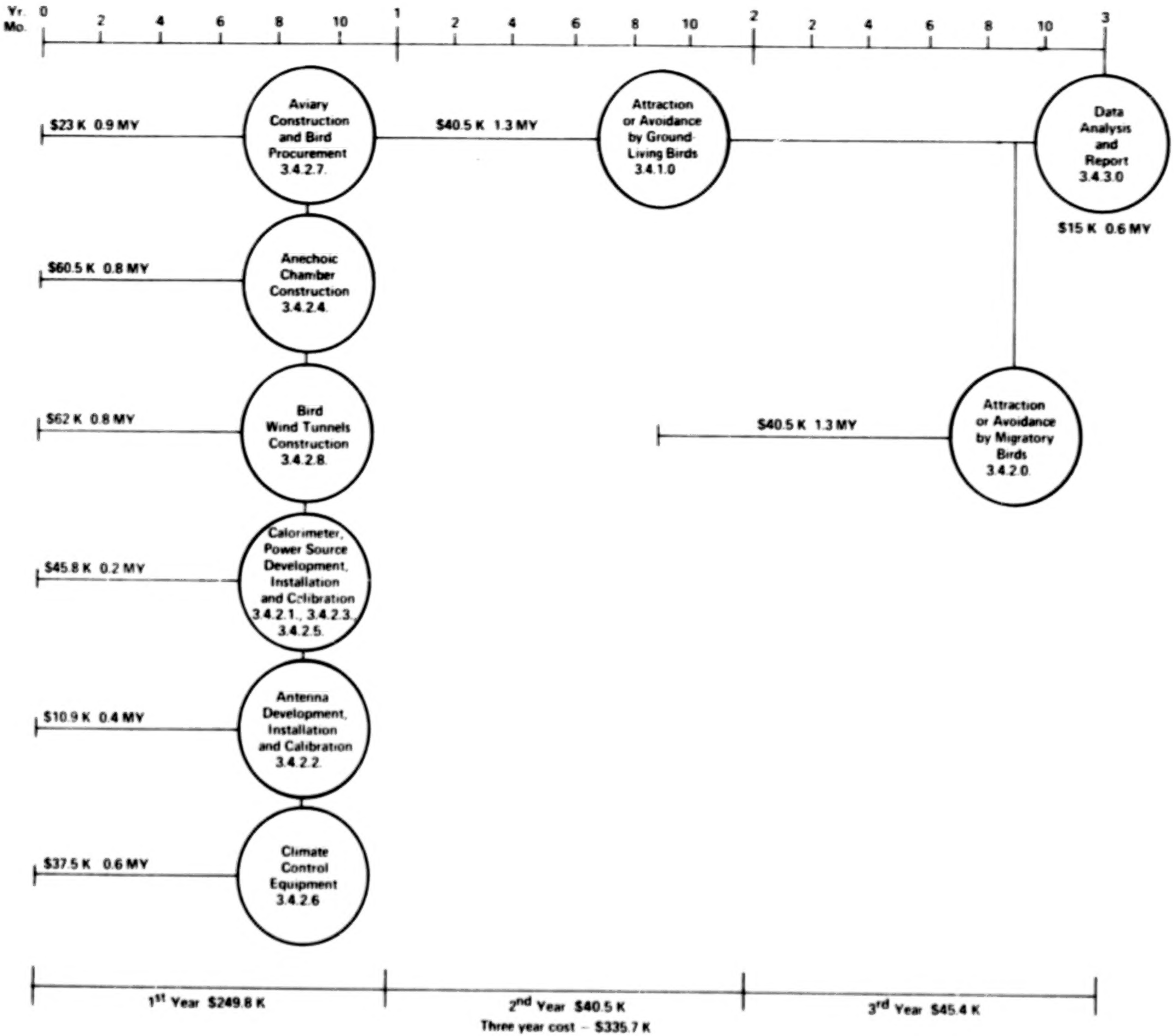

Figure 12

3.5 EFFECTS ON REPRODUCTION AND FLIGHT PATTERNS

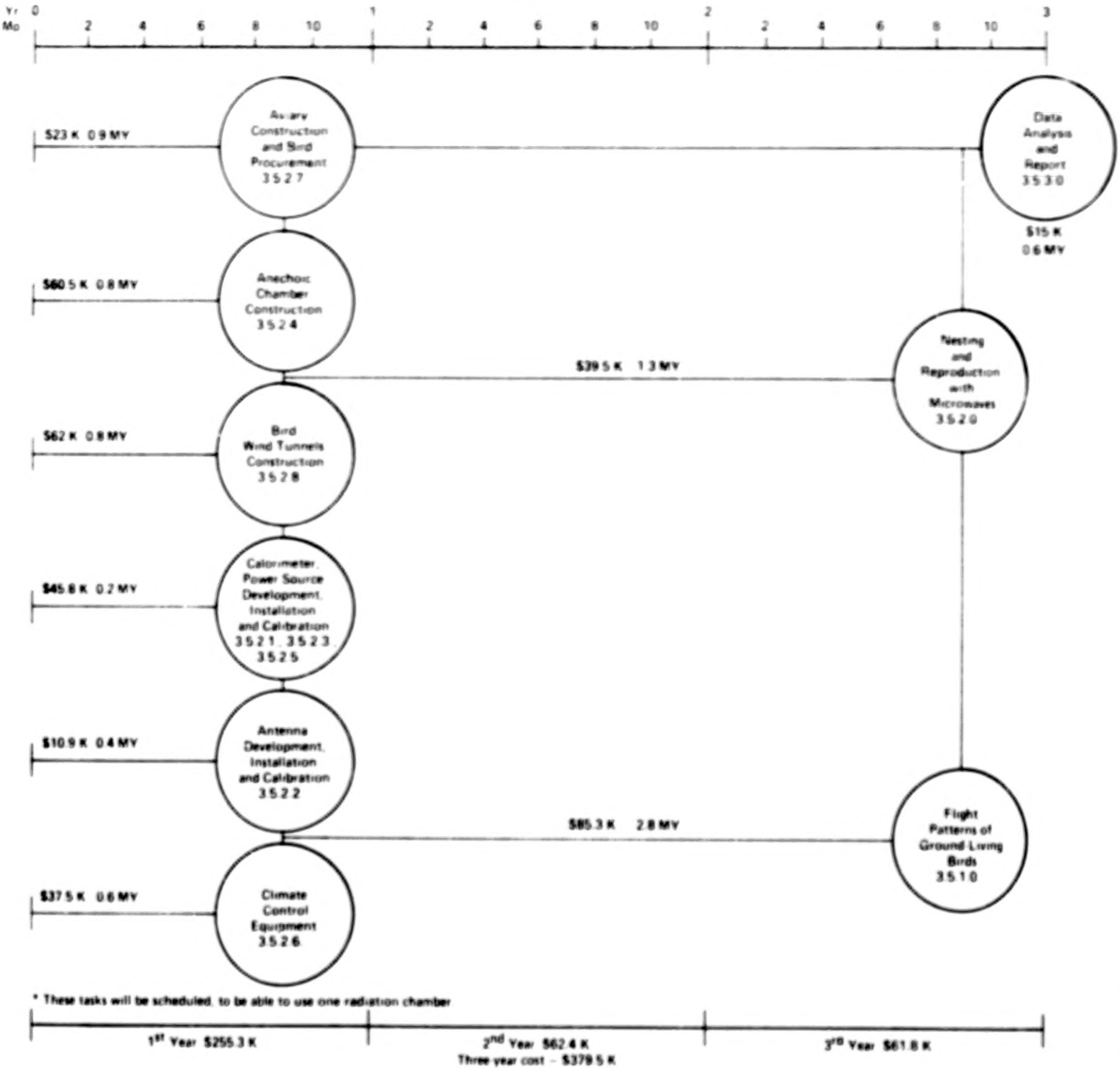

Figure 13

PROTOCOLS

TABLE 42

3.1 BIRD THERMAL STRESS: FLIGHT, FOOD INTAKE, AND MICROWAVES

PROTOCOL 3.1.1.0 COMPUTER SIMULATION OF BODY TEMPERATURE OF BIRDS IN FLIGHT IN A MICROWAVE FIELD

- HYPOTHESIS OR TASK: THE INCREASE IN BODY TEMPERATURE OF BIRDS, AT REST OR FLYING, IN A 2450 MHz CW FIELD AS A FUNCTION OF THE BIRD'S SIZE, SPEED OF FLIGHT, DURATION OF EXPOSURE, AND AMBIENT CONDITIONS OF TEMPERATURE AND ALTITUDE WILL BE SIMULATED BY COMPUTER TO IDENTIFY POSSIBLE LETHAL EFFECTS.
- APPROACH: BASED ON RECENT STUDIES BY TUCKER (1973), THE TOTAL HEAT LOAD OF A BIRD AT REST AND IN FLIGHT CAN BE SIMULATED. THE NET HEAT GAIN FROM 2450 MHz CW FIELDS CAN ALSO BE SIMULATED BY USING THE CALCULATIONS OF GANDHI (1974) TO ARRIVE AT THE GAIN IN BODY TEMPERATURE.
- INFORMATION TO BE DERIVED: THE PROBABLE BODY TEMPERATURE OF A BIRD, AT REST AND DURING FLIGHT IN THE MICROWAVE FIELD, CAN BE IDENTIFIED AS A FUNCTION OF BIRD SIZE AND DURATION IN THE MICROWAVE FIELD. FROM THIS INFORMATION, INFERENCES ABOUT LETHALITY OR PHYSIOLOGICAL DAMAGE CAN BE MADE FOR ANY BIRD SIZE AND A CATALOG OF EFFECTS BY SPECIES OF BIRDS CAN BE MADE.
- EXPERIMENT TIME:

MONTHS TO COMPLETE	12
MAN YEARS	1.1

- COST FOR RESEARCH: $43.2K
- NEW FACILITIES REQUIRED:

TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
NONE			

TABLE 43

3.1 BIRD THERMAL STRESS: FLIGHT, FOOD INTAKE, AND MICROWAVES

PROTOCOL 3.1.2.0 EMPIRICAL VERIFICATION OF COMPUTER-SIMULATED DATA

- HYPOTHESIS OR TASK: THE INCREASE IN BODY TEMPERATURE OF FLYING BIRDS IN A 2450 MHz FIELD AS A FUNCTION OF THE BIRD'S SIZE, SPEED AND DIRECTION OF FLIGHT, DURATION OF EXPOSURE, AND AMBIENT TEMPERATURE WILL BE DETERMINED.
- APPROACH: TO TEST THE VALIDITY OF THE COMPUTER SIMULATED DATA, BIRDS OF REPRESENTATIVE SIZES AND SPECIES WILL BE FLOWN IN A PLEXIGLASS WIND TUNNEL AT DIFFERENT AMBIENT TEMPERATURES WITH AND WITHOUT 2450 MHz CW MICROWAVES.
- INFORMATION TO BE DERIVED: AS A RESULT OF THESE EXPERIMENTS, IT WOULD BE POSSIBLE TO PREDICT THE CONSEQUENCES ON BIRDS FLYING THROUGH THE MICROWAVE FIELD AT DIFFERENT SEASONS OF THE YEAR.
- EXPERIMENT TIME:

MONTHS TO COMPLETE	24
MAN YEARS	2

- COST FOR RESEARCH: $73K
- NEW FACILITIES REQUIRED:

	TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
3.1.2.1	2450 MHz POWER SOURCE	$17.7K	0.2	9 MONTHS
3.1.2.2	ANTENNA DEVELOPMENT	$10.9K	0.4	9 MONTHS
3.1.2.3	CALORIMETER & RECORDER	$8.8K	---	9 MONTHS
3.1.2.4	ANECHOIC CHAMBER	$60.5K	0.8	9 MONTHS
3.1.2.5	POWER & FREQUENCY MONITOR	$19.3K	0.2	9 MONTHS
3.1.2.6	CLIMATE CONTROL EQUIPMENT	$37.5K	0.6	9 MONTHS
3.1.2.7	AVIARY CONSTRUCTION	$23K	0.9	9 MONTHS
3.1.2.8	TWO WIND TUNNELS	$62K	0.8	9 MONTHS

TABLE 44

3.1 BIRD THERMAL STRESS: FLIGHT, FOOD INTAKE, AND MICROWAVES

PROTOCOL 3.1.3.0 BODY TEMPERATURE: MICROWAVE EXPOSURE AND FOOD INTAKE

- o HYPOTHESIS OR TASK: WILL THE BODY TEMPERATURE FOLLOWING FEEDING PLUS THE HEAT INCREMENT IMPOSED BY THE MICROWAVE RADIATION BE LETHAL TO BIRDS?
- o APPROACH: BIRDS WILL BE FLOWN IN A WIND TUNNEL WITH AND WITHOUT 2.45 GHz MICROWAVES AT THE TIMES AFTER EATING THAT THE SPECIFIC DYNAMIC ACTION OF FOOD WILL PRODUCE THE GREATEST INCREMENT IN BODY TEMPERATURE. THIS WILL BE DETERMINED FOR BIRDS OF DIFFERENT SIZES AND DIFFERENT DIETS.
- o INFORMATION TO BE DERIVED: THE BODY TEMPERATURE OF THE BIRD WITH HEAT LOAD FROM THE ABOVE FACTORS WILL BE DETERMINED. INFERENCES ABOUT LETHALITY OR POSSIBLE PHYSIOLOGICAL DAMAGE CAN THEN BE MADE.
- o EXPERIMENT TIME:

MONTHS TO COMPLETE	24
MAN YEARS	2.8

- o COST FOR RESEARCH: $87.8K
- o NEW FACILITIES REQUIRED:

TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
COMMON WITH 3.1.2.0			

3.1 BIRD THERMAL STRESS: FLIGHT, FOOD INTAKE, AND MICROWAVES

PROTOCOL 3.1.4.0 FEEDING, LANDING, AND TAKE-OFF IMPOSED IN THE MICROWAVE FIELD

- o HYPOTHESIS OR TASK: THE THERMAL LOADING AFTER FEEDING, LANDING, AND TAKE-OFF IN A MICROWAVE FIELD WILL NOT BE FATAL TO BIRDS.
- o APPROACH: BIRDS WILL BE FLOWN IN A WIND TUNNEL WITH AND WITHOUT 2.45 GHz MICROWAVES AT THE TIME AFTER EATING THAT THE SPECIFIC DYNAMIC ACTION OF FOOD WILL PRODUCE THE GREATEST INCREMENT IN BODY TEMPERATURE. LANDING AND TAKE-OFF, WHICH REQUIRE APPROXIMATELY 15 TO 20 PERCENT GREATER POWER THAN LEVEL FLIGHT, WILL BE IMPOSED IN THE WIND TUNNEL.
- o INFORMATION TO BE DERIVED: THE BODY TEMPERATURE OF THE BIRD WITH HEAT LOAD FROM THE ABOVE FACTORS WILL BE DETERMINED. INFERENCES ABOUT LETHALITY OR POSSIBLE PHYSIOLOGICAL DAMAGE CAN BE MADE.
- o EXPERIMENT TIME:

MONTHS TO COMPLETE	24
MAN YEARS	2.0

- o COST FOR RESEARCH: $55.2K
- o NEW FACILITIES REQUIRED:

TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
COMMON WITH 3.1.2.0			

3.1 BIRD THERMAL STRESS: FLIGHT, FOOD INTAKE, AND MICROWAVES

PROTOCOL 3.1.5.0 ANALYSIS AND REPORT ON BIRD THERMAL STRESS

- o HYPOTHESIS OR TASK: PREPARE A FINAL REPORT ON THE THREE-YEAR RESEARCH PROGRAM TO INVESTIGATE MICROWAVE ENERGY DEPOSITION IN THE BIRD AND ITS POSSIBLE HARMFUL OR LETHAL EFFECTS.
- o APPROACH: COMPILE AND ANALYZE DATA COLLECTED ON BIRD PERFORMANCE UNDER HEAT STRESS FROM A VARIETY OF FACTORS IN COMPARISON TO THE COMPUTER SIMULATED MODELS.
- o INFORMATION TO BE DERIVED: A CATALOG WILL BE FORMED OF PROBABLE HEAT INCREMENTS AS A FUNCTION OF BIRD SIZE, SPECIES, AMBIENT TEMPERATURE, DURATION AND INTENSITY OF THE 2.45 GHz MICROWAVE FIELD, FLIGHT SPEED, LANDING AND TAKE-OFF, AND MICROWAVE ABSORPTION. AN ESTIMATE OF POSSIBLE IMPAIRMENT OR LETHAL EFFECTS TO BIRDS AS A FUNCTION OF THE ABOVE VARIABLES WILL BE DETERMINED.
- o EXPERIMENT TIME:

MONTHS TO COMPLETE	3
MAN YEARS	.6

- o COST FOR RESEARCH: $15K
- o NEW FACILITIES REQUIRED:

TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
NONE			

TABLE 47

3.2 BIRD THERMAL STRESS: ALTERATIONS OF PROPERTIES OF COLLAGEN IN FLIGHT TENDON AND HEART

PROTOCOL 3.2.1.0 FLIGHT TENDON COLLAGEN STRESSED BY MICROWAVE RADIATION

- o HYPOTHESIS OR TASK: IF ADDITIONAL ENERGY IS IMPOSED UPON A BIRD IN FLIGHT BY MICROWAVE IRRADIATION, WILL THE FLIGHT TENDONS FAIL OR AT LEAST BECOME LESS EFFICIENT IN THE TRANSFER OF FORCE AND MAINTENANCE OF FLIGHT?
- o APPROACH: THE UPPER LIMIT OF PREFERRED TEMPERATURE IN HOMEOTHERMIC LAND ANIMALS CORRELATES WELL WITH THE MELTING POINT OF MOLECULAR COLLAGEN FROM SUCH ORGANISMS. THE RISE IN BODY TEMPERATURE IN BIRDS IN FLIGHT IS LARGE, AS MUCH AS 5^{o} C ABOVE NORMAL. RIGBY'S METHOD SHOULD BE USED TO CONFIRM THE STRESS-RELAXATION BEHAVIOR OF ISOLATED FLIGHT TENDON OF PIGEONS OR RING DOVES.
- o INFORMATION TO BE DERIVED: THE TECHNIQUE INVOLVES THE ANALYSIS OF THE STRESS-RELAXATION BEHAVIOR OF TENDON AS IT IS HEATED. TENDONS SHOULD BE HEATED CONVENTIONALLY AS WELL AS VIA MICROWAVE IRRADIATION. SHOULD THE TENDON FAIL OR BECOME LESS EFFICIENT IN THE TRANSFER OF FORCE BY THE ABOVE HEATING, ONE WOULD HAVE A BASIS FOR SPECIFYING THE HAZARDS TO BIRDS IN SUCH A SYSTEM.
- o EXPERIMENT TIME: MONTHS TO COMPLETE 12 MAN YEARS 1.5
- o COST FOR RESEARCH: $59.6K
- o NEW FACILITIES REQUIRED:

	TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
3.2.1.1	2450 MHz POWER SOURCE	$17.7K	0.2	9 MONTHS
3.2.1 2	ANTENNA DEVELOPMENT	$10.9K	0.4	9 MONTHS
3.2.1.3	CALORIMETER & RECORDER	$8.8K	---	9 MONTHS
3.2.1.4	ANECHOIC CHAMBER	$60.5K	0.8	9 MONTHS
3.2.1.5	POWER & FREQUENCY MONITORS	$10.9K	0.4	9 MONTHS
3.2.1.6	CLIMATE CONTROL EQUIPMENT	$37.5K	0.6	9 MONTHS
3.2.1.7	AVIARY CONSTRUCTION	$23K	0.9	9 MONTHS
3.2.1.8	TWO WIND TUNNELS	$62K	0.8	9 MONTHS

TABLE 48

3.2 BIRD THERMAL STRESS: ALTERATIONS OF PROPERTIES OF COLLAGEN IN FLIGHT TENDON AND HEART

PROTOCOL 3.2.2.0 FLIGHT TENDON COLLAGEN STRESSED BY TAKE-OFF IN THE MICROWAVE FIELD

- HYPOTHESIS OR TASK: THE MAXIMUM STRESS ON FLIGHT TENDONS OCCURS DURING TAKE-OFF AND POSSIBLY LANDING. IF ISOLATED TENDON IS SUBJECTED TO MAXIMUM ELONGATION (≈4 PERCENT OF REST LENGTH), TEMPERATURES NEAR FLIGHT TEMPERATURES, WILL THE TENDON FAIL OR REDUCE THE EFFICIENCY TO THE EXTENT THAT TAKE-OFF MIGHT BE IMPOSSIBLE?
- APPROACH: THE METHOD SHOULD BE THAT OF RIGBY. MICROWAVE IRRADIATION WILL BE ADDED AS THE ULTIMATE HAZARD.
- INFORMATION TO BE DERIVED: THE EFFECT OF TENDON IRRADIATION ON THE ABILITY TO TAKE-OFF AND/OR LAND FOLLOWING EXPOSURE WILL BE AN ASSESSMENT OF THE HAZARD TO BIRDS.
- EXPERIMENT TIME:

MONTHS TO COMPLETE	12
MAN YEARS	1.5

- COST FOR RESEARCH: $56.8K
- NEW FACILITIES REQUIRED:

TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
COMMON WITH 3.2.1.0			

TABLE 49

3.2 BIRD THERMAL STRESS: ALTERATIONS OF PROPERTIES OF COLLAGEN IN FLIGHT TENDON AND HEART

PROTOCOL 3.2.3.0 FLIGHT TENDON COLLAGEN ENDURANCE UNDER REPEATED MICROWAVE EXPOSURE DURING LANDING AND TAKE-OFF

- HYPOTHESIS OR TASK: WILL REPEATED EXPOSURE TO MICROWAVE IRRADIATION UNDER MAXIMUM FLIGHT CONDITIONS RESULT IN A REDUCTION OF ENDURANCE? ISOLATED TENDON FROM ANIMALS SO EXPOSED MAY REVEAL THE ROLE TENDON MIGHT PLAY IN SUCH AN EVALUATION.
- APPROACH: REPEATED EXPOSURE OF ISOLATED TENDON TO CYCLES OF TEMPERATURE NOT EXCEEDING THE CRITICAL TEMPERATURE HAVE NO LASTING EFFECT ON THE TENDON. HOWEVER, IF THE CRITICAL TEMPERATURE IS EXCEEDED, SUBSEQUENT TESTING OF STRESS-RELAXATION SHOWS THE TENDON TO BE LESS EFFICIENT. TENDONS FROM ANIMALS REPEATEDLY EXPOSED TO MICROWAVE IRRADIATION UNDER SIMULATED OR ACTUAL FLIGHT WILL BE KILLED, TENDON ISOLATED, AND TESTED USING RIGBY'S METHOD.
- INFORMATION TO BE DERIVED: SHOULD TENDON FROM ANIMALS REPEATEDLY EXPOSED FAIL OR SHOW PERMANENT MODIFICATION OF STRESS-RELAXATION BEHAVIOR, A FURTHER CONFIRMATION OF HAZARD WILL RESULT. SHOULD THE TENDON INDICATE NO CHANGE, THE HAZARD WILL BE REDUCED.
- EXPERIMENT TIME:

MONTHS TO COMPLETE	18
MAN YEARS	1.5

- COST FOR RESEARCH: $62.9K
- NEW FACILITIES REQUIRED:

TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
COMMON WITH 3.2.1.0			

TABLE 50

3.2 BIRD THERMAL STRESS: ALTERATIONS OF PROPERTIES OF COLLAGEN IN FLIGHT TENDON AND HEART

PROTOCOL 3.2.4.0 FLIGHT TENDON COLLAGEN ENDURANCE UNDER MICROWAVE EXPOSURE AFTER LONG SIMULATED MIGRATORY FLIGHTS

- o HYPOTHESIS OR TASK: NEAR THE TERMINATION OF A LONG MIGRATORY FLIGHT, THE RESOURCES OF THE BIRD ARE MINIMAL. WILL EXPOSURE TO MICROWAVE IRRADIATION AT THIS TIME CHANGE THE BEHAVIOR OF FLIGHT TENDON IN A WAY AT VARIANCE TO REPEATED EXPOSURE ON TAKE-OFF AND LANDING?
- o APPROACH: BIRD SHOULD BE FLOWN TO NEAR FATIGUE IN A WIND TUNNEL, REMOVE THE FLIGHT TENDONS, AND TEST VIA RIGBY'S METHOD. AS A SECOND APPROACH, ONE MAY TEST NATIVE BIRDS, DUCKS, OR THE MOURNING DOVE FOLLOWING LONG FLIGHTS.
- o INFORMATION TO BE DERIVED: SHOULD THE DEPRESSED CONDITION RESULT IN LOWER CRITICAL TEMPERATURES, PREMATURE FAILURE, OR ANY SERIOUS MODIFICATION OF THE STRESS-RELAXATION BEHAVIOR, THE EFFECTS OF SUCH EXPOSURE ON MIGRATORY BIRDS WOULD BE A DISASTER.
- o EXPERIMENT TIME:

MONTHS TO COMPLETE	18
MAN YEARS	1.5

- o COST FOR RESEARCH: $65.3K
- o NEW FACILITIES REQUIRED:

TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
COMMON WITH 3.2.1.0			

TABLE 51

3.2 BIRD THERMAL STRESS: ALTERATIONS OF PROPERTIES OF COLLAGEN IN FLIGHT TENDON AND HEART

PROTOCOL 3.2.5.0 MICROWAVE RADIATION EFFECTS ON BIRD HEART RATE

- HYPOTHESIS OR TASK: WHAT EFFECTS WILL IRRADIATION OF ANIMALS DURING MAXIMUM STRESS CONDITIONS HAVE ON THE HEART? THE ADDITIONAL STRESS WILL BE ESTIMATED BY USING CONTROL VERSUS IRRADIATED GROUPS.
- APPROACH: THE ECG WILL BE RECORDED ON A GRASS RECORDER BY PLACING ELECTRODES AT THE BASE OF THE WINGS. THE BIRDS WILL BE GENTLY RESTRAINED FOR TWO TO FIVE MINUTES TO OBTAIN A STABLE RECORDING. THE BIRD WILL BE RECORDED BOTH BEFORE AND AFTER FLIGHT AND EXPOSURE TO RADIATION. THE PERMANENT RECORDS WILL BE ANALYZED FOR RATE, SHAPE AND FORM, MAGNITUDE, AND POSITION.
- INFORMATION TO BE DERIVED: CHANGES IN ANY OF THE PARAMETERS MAY SEEM TO INDICATE THE TOTAL STRESS ON THE INDIVIDUAL. IN ADDITION THE CHANGE IN THE HEART RATE MAY BE USED AS AN INDICATOR OF METABOLIC RATE.
- EXPERIMENT TIME:

MONTHS TO COMPLETE	15
MAN YEARS	.5

- COST FOR RESEARCH: $20.9K
- NEW FACILITIES REQUIRED:

TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
COMMON WITH 3.2.1.0			

TABLE 52

3.2 BIRD THERMAL STRESS: ALTERATIONS OF PROPERTIES OF COLLAGEN IN FLIGHT TENDON AND HEART

PROTOCOL 3.2.6.0 ANALYSIS AND REPORT ON BIRD THERMAL STRESS AND EFFECTS ON COLLAGEN

- HYPOTHESIS OR TASK: PREPARE A FINAL REPORT ON THE THREE-YEAR RESEARCH PROGRAM TO DETERMINE THE EFFECTS OF MICROWAVE RADIATION ABSORPTION ON THE PROPERTIES OF FLIGHT TENDON AND HEART COLLAGEN.
- APPROACH: COMPILE AND ANALYZE DATA DEVELOPED AND REPORT OR PERFORM NEW EXPERIMENTS WHERE REQUIRED.
- INFORMATION TO BE DERIVED: THE EFFECT OF THERMAL STRESS ON THE STRESS-RELAXATION BEHAVIOR OF TENDON AND HEART AS THEY ARE HEATED BY MICROWAVE ABSORPTION.
- EXPERIMENT TIME:

MONTHS TO COMPLETE	3
MAN YEARS	.6

- COST FOR RESEARCH: $15K
- NEW FACILITIES REQUIRED:

TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
NONE			

TABLE 53

3.3 STIMULUS EFFECTS DURING FLIGHT: AVOIDANCE, INTERFERENCE, OR INTERACTION WITH PHYSIOLOGICAL STATES

PROTOCOL 3.3.1.0 AVOIDANCE OF A MICROWAVE FIELD BY BIRDS IN FLIGHT

- o HYPOTHESIS OR TASK: WILL THE BIRDS IN FLIGHT AVOID A 2450 MHz CW FIELD?
- o APPROACH: BIRDS ARE "WIDE BAND" THERMOREGULATORS AND REGULATE AROUND A RANGE OF BODY TEMPERATURES RATHER THAN A NARROW FIXED POINT AS IS THE USUAL CASE FOR MAMMALS. WITH SUCH A RANGE OF POSSIBLE BODY TEMPERATURES, BIRDS MAY NOT DETECT RISES IN BODY TEMPERATURE ASSOCIATED WITH SUCH THINGS AS FEEDING, GENERAL ACTIVITY, OR FLIGHT UNTIL IT REACHES A CRITICAL UPPER LIMIT OF THE BODY TEMPERATURE RANGE. BIRDS, OF A VARIETY OF SIZES AND SPECIES, SHOULD BE TESTED IN A WIND TUNNEL AND, WHILE FLYING, BE GIVEN AN OPTION TO FLY IN ONE DIRECTION TO AVOID THE MICROWAVE FIELD, OR IN ANOTHER DIRECTION WHERE THEY STAY IN THE FIELD.
- o INFORMATION TO BE DERIVED: TO DETERMINE 1) WHETHER A BIRD FLYING INTO A MICROWAVE FIELD WILL ATTEMPT TO AVOID IT OR NOT, 2) THE TYPE OF AVOIDANCE RESPONSE IT WILL MAKE, 3) WHETHER ANY OR ALL OF THE TESTED SPECIES WILL AVOID A MICROWAVE FIELD WHILE THEY ARE IN FLIGHT, 4) WHETHER AVOIDANCE IS A FUNCTION OF THE BIRDS' SIZE OR SPECIES.
- o EXPERIMENT TIME: MONTHS TO COMPLETE 24 MAN YEARS 2
- o COST FOR RESEARCH: $55.3K
- o NEW FACILITIES REQUIRED:

	TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
3.3.1.1	2450 MHz POWER SOURCE	$17.7K	0.2	9 MONTHS
3.3.1.2	ANTENNA DEVELOPMENT	$10.9K	0.4	9 MONTHS
3.3.1.3	CALORIMETER & RECORDER	$8.8K	---	9 MONTHS
3.3.1.4	ANECHOIC CHAMBER	$60.5K	0.8	9 MONTHS
3.3.1.5	POWER & FREQUENCY MONITORS	$19.3K	0.2	9 MONTHS
3.3.1.6	CLIMATE CONTROL EQUIPMENT	$37.5K	0.6	9 MONTHS
3.3.1.7	AVIARY CONSTRUCTION	$23K	0.9	9 MONTHS
3.3.1.8	TWO WIND TUNNELS	$62K	0.8	9 MONTHS

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TABLE 54

112 3.3 STIMULUS EFFECTS DURING FLIGHT: AVOIDANCE, INTERFERENCE, OR INTERACTION WITH PHYSIOLOGICAL STATES

PROTOCOL 3.3.2.0 EFFECTS OF MICROWAVE IRRADIATION ON BIRD NAVIGATION

- HYPOTHESIS OR TASK: WILL THE ABILITY OF HOMING PIGEONS TO NAVIGATE TO THEIR HOME CAGES BE ALTERED BY MICROWAVE RADIATION?
- APPROACH: HOMING PIGEONS CAN BE TRAINED TO FLY FROM THE LOCATION OF THE WIND TUNNEL TO THEIR HOME CAGES, LOCATED NO CLOSER THAN 50 MILES AWAY. AT LEAST FOUR DIFFERENT HOME CAGE SITES SHOULD BE USED SO THAT A VARIETY OF FLIGHT DIRECTIONS ON THE COMPASS ARE TESTED. UPON COMPLETION OF A SIMULATED FLIGHT IN THE MICROWAVE FIELD IN A WIND TUNNEL, THEY SHOULD BE RELEASED TO FLY TO THEIR HOME CAGES. THE BIRDS WILL BE RELEASED DURING CLEAR SUNNY DAYS, DURING OVERCAST DAYS, DURING CLEAR MOONLIT NIGHT, DURING MOONLESS OVERCAST NIGHTS (IF THE WEATHER PERMITS), AND UNDER A VARIETY OF WIND CONDITIONS AND LIGHT/DARK CYCLES, BOTH BEFORE AND AFTER THE FLIGHT THROUGH THE MICROWAVE FIELD.
- INFORMATION TO BE DERIVED: ONE MAY BE ABLE TO IDENTIFY THE LIGHT, SEASONAL, AND WEATHER CONDITIONS UNDER WHICH FLIGHT IN A MICROWAVE FIELD MAY PRODUCE DISORIENTATION IN THE HOMING OF PIGEONS. THIS WOULD BE IDENTIFIED AS A CHANGE IN ROUTE OR AN IRREGULAR ROUTE THAT LASTED FOR A GIVEN PERIOD OF TIME, OR RESULTED IN THE BIRD BEING PERMANENTLY LOST.
- EXPERIMENT TIME:

MONTHS TO COMPLETE	24
MAN YEARS	4

- COST FOR RESEARCH: $200.8K
- NEW FACILITIES REQUIRED:

TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
COMMON WITH 3.3.1.0			

TABLE 55

3.3 STIMULUS EFFECTS DURING FLIGHT: AVOIDANCE, INTERFERENCE, OR INTERACTION WITH PHYSIOLOGICAL STATES

PROTOCOL 3.3.3.0 EFFECTS OF 2.45 GHz MICROWAVE RADIATION ON MIGRATION BEHAVIOR

- HYPOTHESIS OR TASK: THERE WILL BE NO DIFFERENTIAL EFFECT OF MICROWAVE RADIATION WHETHER IT OCCURS EARLY OR LATE IN A SIMULATED MIGRATORY FLIGHT UPON THE AVOIDANCE BEHAVIOR OF BIRDS IN THE MICROWAVE FIELD.
- APPROACH: DURING LONG MIGRATORY FLIGHTS, BIRDS CONSUME THEIR BODY FAT AND MAY LOSE AS MUCH AS 35 TO 40 PERCENT OF THEIR BODY WEIGHT DURING A SINGLE MIGRATORY FLIGHT AND ARE USUALLY IN A STATE OF RELATIVE DEHYDRATION. THUS, A BIRD IS IN A DIFFERENT PHYSIOLOGICAL STATE AFTER A LONG MIGRATORY FLIGHT THAN IT IS WHEN IT FIRST STARTS THAT FLIGHT. AFTER THE BIRDS HAVE SHOWN THEIR PREMIGRATORY FATTENING, THEY CAN BE PLACED IN THE WIND TUNNEL USED FOR AVOIDANCE BEHAVIOR. AFTER THEIR SIMULATED MIGRATORY FLIGHT HAS BEGUN, SOME WILL FLY IN THE SIMULATED MICROWAVE FIELD EARLY IN THEIR MIGRATORY FLIGHT, WHILE OTHERS WILL FLY IN THE SIMULATED MICROWAVE FIELD LATE IN THEIR SIMULATED MIGRATORY FLIGHT.
- INFORMATION TO BE DERIVED: THE BIRDS MAY AVOID THE MICROWAVE FIELD AS A FUNCTION OF THEIR PHYSIOLOGICAL STATE, OR THE MODE OF ATTEMPTING TO AVOID THE FIELD MAY CHANGE WITH THE PHYSIOLOGICAL STATE. THE BIRDS IN THE MICROWAVE FIELD EARLY IN THE FLIGHT MAY ATTEMPT TO AVOID THE MICROWAVE FIELD BY FLYING FASTER OR CHANGING DIRECTION, WHILE THOSE ENTERING THE FIELD LATER IN THEIR SIMULATED MIGRATORY FLIGHT MAY ATTEMPT TO LAND AND, IF THEY ARE DEHYDRATED, THAT COULD BE FATAL FOR THEM.
- EXPERIMENT TIME: MONTHS TO COMPLETE 24 MAN YEARS 2.8
- COST FOR RESEARCH: $85.8
- NEW FACILTIES REQUIRED:

TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
COMMON WITH 3.3.1.0			

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TABLE 56

3.3 STIMULUS EFFECTS DURING FLIGHT: AVOIDANCE, INTERFERENCE, OR INTERACTION WITH PHYSIOLOGICAL STATES

PROTOCOL 3.3.4.0 ANALYSIS AND REPORT ON STIMULUS EFFECTS OF MICROWAVE RADIATION ON BIRDS DURING FLIGHT

- HYPOTHESIS OR TASK: PREPARE A FINAL REPORT ON THE THREE-YEAR RESEARCH PROGRAM TO DETERMINE THE EFFECTS OF MICROWAVE ABSORPTION ON THE AVOIDANCE OF THE FIELD, AVOIDANCE AS A FUNCTION OF PHYSIOLOGICAL STATE OR POSSIBLE EFFECTS ON NAVIGATION.
- APPROACH: COMPILE AND ANALYZE DATA DEVELOPED AND REPEAT OR PERFORM NEW EXPERIMENTS WHERE REQUIRED.
- INFORMATION TO BE DERIVED: THE EFFECTS OF MICROWAVE-INDUCED THERMAL STRESS ON BIRD AVOIDANCE, NAVIGATION AND INTERACTION WITH ALTERED PHYSIOLOGICAL STATES DURING MIGRATORY FLIGHT.
- EXPERIMENT TIME:

MONTHS TO COMPLETE	3
MAN YEARS	.6

- COST FOR RESEARCH: $15K
- NEW FACILITIES REQUIRED:

TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
NONE			

TABLE 57

3.4 ATTRACTION TO OR AVOIDANCE OF THE RECTENNA SITE: DIFFERENT AMBIENT TEMPERATURES

PROTOCOL 3.4.1.0 ATTRACTION TO OR AVOIDANCE OF GROUND-LIVING BIRDS TO THE MICROWAVE FIELD AT DIFFERENT AMBIENT TEMPERATURES

- HYPOTHESIS OR TASK: GROUND-LIVING BIRDS WILL BE ATTRACTED TO THE MICROWAVE FIELD AT LOW AMBIENT TEMPERATURES AND AVOID THE MICROWAVE FIELD AT HIGH AMBIENT TEMPERATURES.
- APPROACH: MORTON (1966) AND HAMILTON AND HEPNER (1967) HAVE EXPOSED BIRDS TO RADIANT SOLAR ENERGY OR ARTIFICIAL RADIATION AND HAVE DEMONSTRATED THAT BIRDS ATE LESS FOOD. PRESUMABLY THEY CAN, TO SOME EXTENT, EXCHANGE SOLAR ENERGY FOR FOOD. TO INVESTIGATE THE EXTENT THAT BIRDS WILL INTERCHANGE ENERGY AT 2450 MH_Z FOR FOOD AT LOW AMBIENT TEMPERATURES, BIRDS WILL BE ALLOWED TO SEEK OR AVOID A HIGH-LEVEL (25 mW/cm^2) RADIATION FIELD WITH AMBIENT TEMPERATURES RANGING FROM -10^{o} C TO $+30^{o}$ C AND WITH THE FOOD SUPPLY VARYING FROM PLENTIFUL TO VERY SPARSE.
- INFORMATION TO BE DERIVED: TO DETERMINE IF GROUND-LIVING BIRDS WILL SEEK THE MICROWAVE FIELD AND ABSORB MICROWAVE RADIATION DURING THE WINTER TIME WHEN IT IS COLD AND FOOD IS SCARCE AND AVOID THE FIELD IN THE SUMMER.
- EXPERIMENT TIME: MONTHS TO COMPLETE 24 MAN YEARS 1.3
- COST FOR RESEARCH: $40.5K
- NEW FACILITIES REQUIRED:

	TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
3.4.1.1	2450 MHz POWER SOURCE	$17.7K	0.2	9 MONTHS
3.4.1.2	ANTENNA DEVELOPMENT	$10.9K	0.4	9 MONTHS
3.4.1.3	CALORIMETER & RECORDER	$8.8K	---	9 MONTHS
3.4.1.4	ANECHOIC CHAMBER	$60.5K	0.8	9 MONTHS
3.4.1.5	POWER & FREQUENCY MONITORS	$19.3K	0.2	9 MONTHS
3.4.1.6	CLIMATE CONTROL EQUIPMENT	$37.5K	0.6	9 MONTHS
3.4.1.7	AVIARY CONSTRUCTION	$23K	0.9	9 MONTHS
3.4.1.8	TWO WIND TUNNELS	$62K	0.8	9 MONTHS

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TABLE 58

3.4 ATTRACTION TO OR AVOIDANCE OF THE RECTENNA SITE: DIFFERENT AMBIENT TEMPERATURES

PROTOCOL 3.4.2.0 ATTRACTION TO OR AVOIDANCE OF MIGRATORY BIRDS TO THE MICROWAVE FIELD

- HYPOTHESIS OR TASK: MIGRATORY SPECIES WILL BE ATTRACTED TO THE MICROWAVE FIELD AT LOW AMBIENT TEMPERATURES.
- APPROACH: MORTON (1966) AND HAMILTON AND HEPNER (1967) HAVE EXPOSED BIRDS TO RADIANT SOLAR ENERGY OR ARTIFICIAL RADIATION AND HAVE DEMONSTRATED THAT BIRDS ATE LESS FOOD. PRESUMABLY THEY CAN, TO SOME EXTENT, EXCHANGE SOLAR ENERGY FOR FOOD. TO INVESTIGATE THE EXTENT THAT BIRDS WILL INTERCHANGE ENERGY AT 2450 MHz FOR FOOD AT LOW AMBIENT TEMPERATURES, BIRDS WILL BE ALLOWED TO SEEK OR AVOID A HIGH-LEVEL (25 mW/cm^2) RADIATION FIELD WITH AMBIENT TEMPERATURES RANGING FROM -10^o C TO $+30^o$ C AND WITH THE FOOD SUPPLY VARYING FROM PLENTIFUL TO VERY SPARSE. THE MIGRATORY SPECIES WILL BE FLOWN IN THE WIND TUNNEL TO SIMULATE THE MIGRATORY FLIGHT STRESS.
- INFORMATION TO BE DERIVED: TO DETERMINE IF BIRDS WILL SEEK THE MICROWAVE FIELD AND ABSORB MICROWAVE RADIATION DURING THE WINTER TIME WHEN IT IS COLD AND FOOD IS SCARCE AND AVOID THE FIELD IN THE SUMMER. BY USING SEVERAL SPECIES OF BIRDS, IT MAY BE POSSIBLE TO ESTIMATE WHETHER BIRDS THAT WOULD NORMALLY MIGRATE TO WARMER CLIMES WOULD INSTEAD STAY IN THE MICROWAVE FIELD AND NOT MIGRATE.
- EXPERIMENT TIME:

MONTHS TO COMPLETE	12
MAN YEARS	1.3

- COST FOR RESEARCH: $40.5K
- NEW FACILITIES REQUIRED:

TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
COMMON WITH 3.4.1.0			

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TABLE 59

3.4 ATTRACTION TO OR AVOIDANCE OF THE RECTENNA SITE: DIFFERENT AMBIENT TEMPERATURES

PROTOCOL 3.4.3.0 ANALYSIS AND REPORT ON ATTRACTION TO OR AVOIDANCE OF THE RECTENNA SITE BY BIRDS

- HYPOTHESIS OR TASK: PREPARE A FINAL REPORT ON THE THREE-YEAR RESEARCH PROGRAM TO DETERMINE WHETHER BIRDS AVOID THE RECTENNA SITE DURING WARM AMBIENT TEMPERATURES OR ARE ATTRACTED AT LOW AMBIENT TEMPERATURES.
- APPROACH: COMPILE AND ANALYZE DATA DEVELOPED AND REPEAT OR PERFORM NEW EXPERIMENTS AS REQUIRED.
- INFORMATION TO BE DERIVED: ESTIMATE THE RELATIVE ATTRACTIVENESS OF THE RECTENNA SITE TO BIRDS, DEPENDING ON SEASON AND AMBIENT TEMPERATURE.
- EXPERIMENT TIME:

MONTHS TO COMPLETE	3
MAN YEARS	.6

- COST FOR RESEARCH: $15K
- NEW FACILITIES REQUIRED:

TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
NONE			

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TABLE 60

3.5 LIVING IN THE RECTENNA SITE: EFFECTS ON REPRODUCTION AND FLIGHT PATTERNS

PROTOCOL 3.5.1.0 EFFECTS OF MICROWAVE RADIATION ON BEHAVIOR PATTERNS OF GROUND-LIVING BIRDS

- HYPOTHESIS OR TASK: THE DURATION OF FLIGHT AND REPRODUCTIVE EFFICIENCY OF BIRDS THAT LIVE PRIMARILY ON THE GROUND (E.G., GALLIFORMES) WILL NOT BE AFFECTED BY LIVING IN A LOW-LEVEL MICROWAVE FIELD AND FREQUENT FLYING IN A HIGH-LEVEL MICROWAVE FIELD.
- APPROACH: MANY BIRDS SUCH AS TURKEYS, QUAIL, PHEASANTS (GALLIFORMES) LIVE AND FEED PRIMARILY ON THE GROUND. THEY FLY ONLY FOR SHORT DISTANCES AND ARE NOT CAPABLE OF FLIGHT FOR LONG DISTANCES. FLIGHT IS USED PRIMARILY TO ESCAPE PREDATORS. IF REPEATED SHORT FLIGHTS IN THE HIGH-LEVEL FIELD PRODUCED A PROGRESSIVELY SHORTER FLIGHT, THESE BIRDS WOULD BECOME VERY VULNERABLE TO PREY. BOTH MALE AND FEMALE PHEASANTS WILL BE GIVEN DAILY FLIGHTS, ONE OR TWO MINUTES IN DURATION. HALF OF EACH GROUP WILL BE RADIATED WHILE FLYING. EACH EXPERIMENTAL ANIMAL WILL BE HOUSED WITH A NONEXPERIMENTAL ANIMAL OF THE OPPOSITE SEX. THE NESTING, EGG-LAYING, AND BROODING BEHAVIOR WILL BE COMPARED WITH CONTROLS. A SPRING MODE LIGHT/DARK CYCLE WILL BE USED THROUGHOUT THE EXPERIMENT.
- INFORMATION TO BE DERIVED: THE EFFECT OF REPEATED FLIGHTS IN THE MICROWAVE FIELD UPON ENDURANCE AND REPRODUCTIVE BEHAVIORS CAN BE IDENTIFIED. THIS IN TURN SHOULD PROVIDE A ROUGH INDEX OF WHETHER BIRDS CAN SURVIVE AND REPRODUCE AT AN ANTENNA SITE.
- EXPERIMENT TIME: MONTHS TO COMPLETE 24 MAN YEARS 2.8
- COST FOR RESEARCH: $85.3K
- NEW FACILITIES REQUIRED:

	TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
3.5.1.1-.5	2.45 GHz EXPOSURE FACILITIES	$117.2K	1.6	9 MONTHS
3.5.1.6	CLIMATE CONTROL EQUIPMENT	$37.5K	0.6	9 MONTHS
3.5.1.7	AVIARY CONSTRUCTION	$23K	0.9	9 MONTHS
3.5.1.8	TWO WIND TUNNELS	$62K	0.8	9 MONTHS

TABLE 61

3.5 LIVING IN THE RECTENNA SITE: EFFECTS ON REPRODUCTION AND FLIGHT PATTERNS

PROTOCOL 3.5.2.0 EFFECTS OF INFREQUENT MICROWAVE RADIATION EXPOSURE ON NESTING AND REPRODUCTION

- HYPOTHESIS OR TASK: LOW-LEVEL RADIATION (2450 MHz CW 1 mW/cm^2) WILL NOT ALTER THE NESTING AND REPRODUCTIVE BEHAVIOR OF RING DOVES.
- APPROACH: THIS EXPERIMENT INVESTIGATES THE EFFECTS OF CONTINUOUS EXPOSURE TO 1 mW/cm^2 2450 MHz CW RADIATION UPON THE REPRODUCTIVE CYCLE OF RING DOVES. THIS SPECIES (STREPTOPELIA RISORIA: ORDER COLUMBIFORMES) IS SELECTED FOR THE STUDY OF REPRODUCTIVE BEHAVIOR BECAUSE THE BEHAVIORAL AND HORMONAL SYSTEMS THAT MAINTAIN THAT BEHAVIOR ARE WELL KNOWN. THE BEHAVIORAL SEQUENCE INCLUDES COURTSHIP, MATING, NESTING, AND CARE FOR THE SQUABS. SEVERAL PAIRS OF RING DOVES WILL BE CONTINUOUSLY EXPOSED TO RADIATION (1 mW/cm^2) AND THEIR BEHAVIOR MONITORED THROUGH THREE COMPLETE REPRODUCTIVE CYCLES.
- INFORMATION TO BE DERIVED: DOES LOW-LEVEL RADIATION DISRUPT THE REPRODUCTIVE CYCLE OF RING DOVES? IF IT DOES NOT, A PHYSIOLOGICAL ANALYSIS OF THE BIRDS' HORMONAL SYSTEM WILL BE GIVEN LOW PRIORITY. IF THE REPRODUCTIVE CYCLE IS DISRUPTED, ANALYSIS OF HORMONAL SYSTEM ALTERATIONS SHOULD BE GIVEN HIGH PRIORITY. IN ADDITION, THE YOUNG THAT ARE HATCHED AND RAISED IN THE RADIATION FIELD CAN BE RAISED AND TESTED FOR FERTILITY.
- EXPERIMENT TIME:

MONTHS TO COMPLETE	12
MAN YEARS	1.3

- COST FOR RESEARCH: $39.5K
- NEW FACILITIES REQUIRED:

TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
COMMON WITH 3.5.1.0			

TABLE 62

3.5 LIVING IN THE RECTENNA SITE: EFFECTS ON REPRODUCTION AND FLIGHT PATTERNS

PROTOCOL 3.5.3.0 ANALYSIS AND REPORT ON REPRODUCTION AND FLIGHT PATTERNS OF BIRDS LIVING IN THE RECTENNA SITE

- HYPOTHESIS OR TASK: PREPARE A FINAL REPORT ON THE THREE-YEAR RESEARCH PROGRAM TO DETERMINE WHETHER INFREQUENT INTENSE AND CHRONIC LOW-LEVEL EXPOSURE TO THE MICROWAVE FIELD WILL IMPAIR FLIGHT AND REPRODUCTION OF GROUND-LIVING BIRDS.
- APPROACH: COMPILE AND ANALYZE DATA DEVELOPED AND REPEAT OR PERFORM NEW EXPERIMENTS AS REQUIRED.
- INFORMATION TO BE DERIVED: ESTIMATE THE EFFECT OF INFREQUENT INTENSE AND CHRONIC LOW-LEVEL MICROWAVE EXPOSURE ON ABILITY TO FLY AND ESCAPE PREDATORS, AND NESTING AND REPRODUCTION OF GROUND-LIVING BIRDS.
- EXPERIMENT TIME:

MONTHS TO COMPLETE	3
MAN YEARS	.6

- COST FOR RESEARCH: $15K
- NEW FACILITIES REQUIRED:

TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
NONE			

MILESTONE AND FUNDING SUMMARY

TABLE 41

MILESTONE AND FUNDING SUMMARY

	Phase A Year 0	1	2	3	Cost $K Exper.	Facil.	Question
3.1.0.0 Bird Thermal Stress: Flight, Food Intake, and Microwaves				▽	--	---	514
3.1.1.0 Computer Simulation		▽			43	---	
3.1.2.0 Empirical Verification of Computer Simulated Data				▽	73	240	
3.1.3.0 Body Temperature: Food Intake and Microwave Exposure				▽	88	---	
3.1.4.0 Feeding, Landing and Takeoff				▽	55	---	
3.1.5.0 Analysis and Report				▽	15	---	
3.2.0.0 Bird Thermal Stress: Alterations of Properties of Collagens in Flight Tendon and Heart				▽	--	---	520
3.2.1.0 Microwave Effect on Flight Tendon Collagen		▽			60	240	
3.2.2.0 Flight Tendon Stressed by Takeoff in Microwave Fields			▽		57	---	
3.2.3.0 Flight Tendon Endurance				▽	63	---	

TABLE 41. - Continued

	PHASE A YEAR				COST $K		
	0	1	2	3	Exper.	Facil.	Question
3.2.4.0 Flight Tendon Endurance under Migratory Flights				∇	65	---	
3.2.5.0 Bird Heart Rate				∇	21	---	
3.2.6.0 Analysis and Report				∇	15	---	
3.3.0.0 Stimulus Effects During Flight: Avoidance, Interference, or Interaction with Physiological States				∇	--	---	622
3.3.1.0 Avoidance of Microwave Fields				∇	55	240	
3.3.2.0 Effects of Microwave on Bird Navigation				∇	201	25	
3.3.3.0 Effects of Microwave on Bird Migration				∇	86	---	
3.3.4.0 Analysis and Report				∇	15	---	
3.4.0.0 Attraction/Avoidance of Rectenna Site				∇	--	---	336
3.4.1.0 Attraction/Avoidance by Ground-Living Birds			∇		40	240	

TABLE 41. - Concluded

	PHASE A YEAR				COST $K		
	0	1	2	3	Exper.	Facil.	Question
3.4.2.0 Attraction/Avoidance by Migratory Birds				∇	41	---	
3.4.3.0 Analysis and Report				∇	15	---	
3.5.0.0 Effects on Reproduction and Flight Patterns				∇	--	---	380
3.5.1.0 Flight Patterns of Ground-Living Birds				∇	85	240	
3.5.2.0 Nesting and Reproduction with Microwaves				∇	40	---	
3.5.3.0 Analysis and Report				∇	15	---	

PILOT EXPERIMENTATION

ATTRACTION AND AVOIDANCE OF *PASSER DOMESTICUS* TO CW 2.45 GHz MICROWAVES

Eight house sparrows (*Passer domesticus*) were housed under a 14-10 hour on-off light/dark cycle in a CW 2.45 GHz microwave anechoic chamber. Two perch stands, each with four movable perches connected to microswitches, were provided in the chamber. One perch stand was placed 4.5 ft. in front of a 2450 MHz microwave horn antenna, while the other control perch was placed at a further distance lateral to the horn antenna. Microwave fields at the perches averaged 50 and 2 mW/cm^2 power density at the nearest and most distant perches from the horn, respectively. The amount of time spent by one or more birds on each perch was studied under warm (29.5° C.) and cool (8° C.) ambient environmental temperatures. While the results indicate that the house sparrow may be attracted to microwave fields at 50 mW/cm^2 during cold ambient temperatures, further experimentation will be required to firmly establish this effect.

VI. EFFECT OF CW 2.45 GHz MICROWAVE ILLUMINATION ON HETEROTHERMS*

SIGNIFICANCE OF CATEGORY

Heterotherms or heliotherms are animals that regulate body temperature by behavioral means. Within the vertebrates these include the reptiles, fishes, and amphibians. These forms are often called "cold-blooded", suggesting that body temperature may be near the ambient soil-air interface. This is true for the fish and amphibians, but reptiles can regulate temperature considerably higher than the air. Several systems have evolved to enhance the ability to trap radiant energy. For example, many can change color rapidly by the use of chromatophores. Orientation of the body is another mechanism for maximum interception or to minimize interception; and many use behavioral means to avoid or seek out radiant energy in the environment, such as shade seeking.

Lizards and snakes are two of such forms of heterotherms which could be influenced by a change or addition to the environment of a source of energy such as the SPS power system.

The first question to be investigated is whether or not these forms can detect microwave energy. In the case of rattlesnakes, boas, and anacondas, studies have shown that these forms detect microwave energy at very low-levels, well below 10 mW/cm^2, apparently by means of infrared receptors. Unlike the above, diurnal snakes do not have specialized infrared detectors, but still may use the energy. Lizards use direct solar radiation to select a preferred body temperature.

*Abstracted from the Final Report for Ames Research Center, NASA Contract NAS2-9555 "2450 MHz Microwave Absorption in Large and Small Animals and Its Biobehavioral Effects on Birds and Reptiles", Om P. Gandhi, H. Clarke Nielson, James L. Lords, John A. D'Andrea, Orlando Cuellar, and Mark J. Hagmann, University of Utah, February 2, 1978

PRIORITIZED LIST OF QUESTIONS

1. CAN HETEROTHERMS, SPECIFICALLY LIZARDS, SNAKES, AND AMPHIBIANS DETECT AND USE A MICROWAVE SOURCE AND THEREBY REGULATE IN SUCH AN ENVIRONMENT; AND, AS A COROLLARY, WILL THE ANIMALS BE ATTRACTED TO OR AVOID SUCH A SOURCE?

2. WILL THE REPRODUCTIVE BEHAVIOR AND POSSIBLE RESULTANT CHANGES IN THE POPULATION DYNAMICS OF THESE FORMS BE MODIFIED BY THE ADDITION OF SUCH A SOURCE OF ENERGY?

The species shown in Table 64 are all amenable to laboratory conditions.

TABLE 64. - SPECIES TO BE USED

Name	Common Name
Lizards:	
Cnemidophorus tigris	Western whiptail
Cnemidophorus uniparens	Whiptail (parthenogenetic)
Sceloporus occidentalis	Western fence lizard
Sceloporus graciosus	Sagebrush lizard
Crotaphytus wislizenii	Leopard lizard
Snakes:	
Thamnophis sirtalis	Common garter snake
Crotalus viridis, lutosus	Great Basin rattlesnake

a. *Cnemidophorus tigris* -- this is a species for which some preliminary data is available (Cuellar, unpublished data).

b. *Cnemidophorus uniparens* -- the use of this unisexual species is especially well suited for the reproductive study, since much is already known concerning its reproductive biology.

c. The other three lizards can be used as a basis for comparative data.

d. Snakes:

1) The garter snake has been selected because it is a diurnal form and because it has not been ascertained whether this species can detect and use microwave energy.

2) The rattlesnake was selected to reconfirm previous studies of detection of microwave power. Previous studies used, evoked potentials in the CNS as the detection system. It is also necessary to ascertain what effect a constant, broad or diffuse, source will have on these forms. The crotalids are nocturnal and seek and attack prey species by sensing their heat.

In addition to the reptilian forms indicated in Table 64, representatives of terrestrial and possibly aquatic amphibians can be included. This would then include representatives of most of the vertebrate heterotherms.

For each of the experimental species, the mass normalized specific absorption rate (SAR) must be determined in several orientations relative to the incident $\vec{E}$ field vector. For all species used, comparative studies between the behavior in the field, under infrared and infrared plus microwave illumination, is the basis of this work. Simulated SPS microwave power is continuous, and analogous to the natural source of solar energy, + SPS power -.

PLANNING CHARTS

4.1 MICROWAVE EFFECTS ON HETEROTHERMS

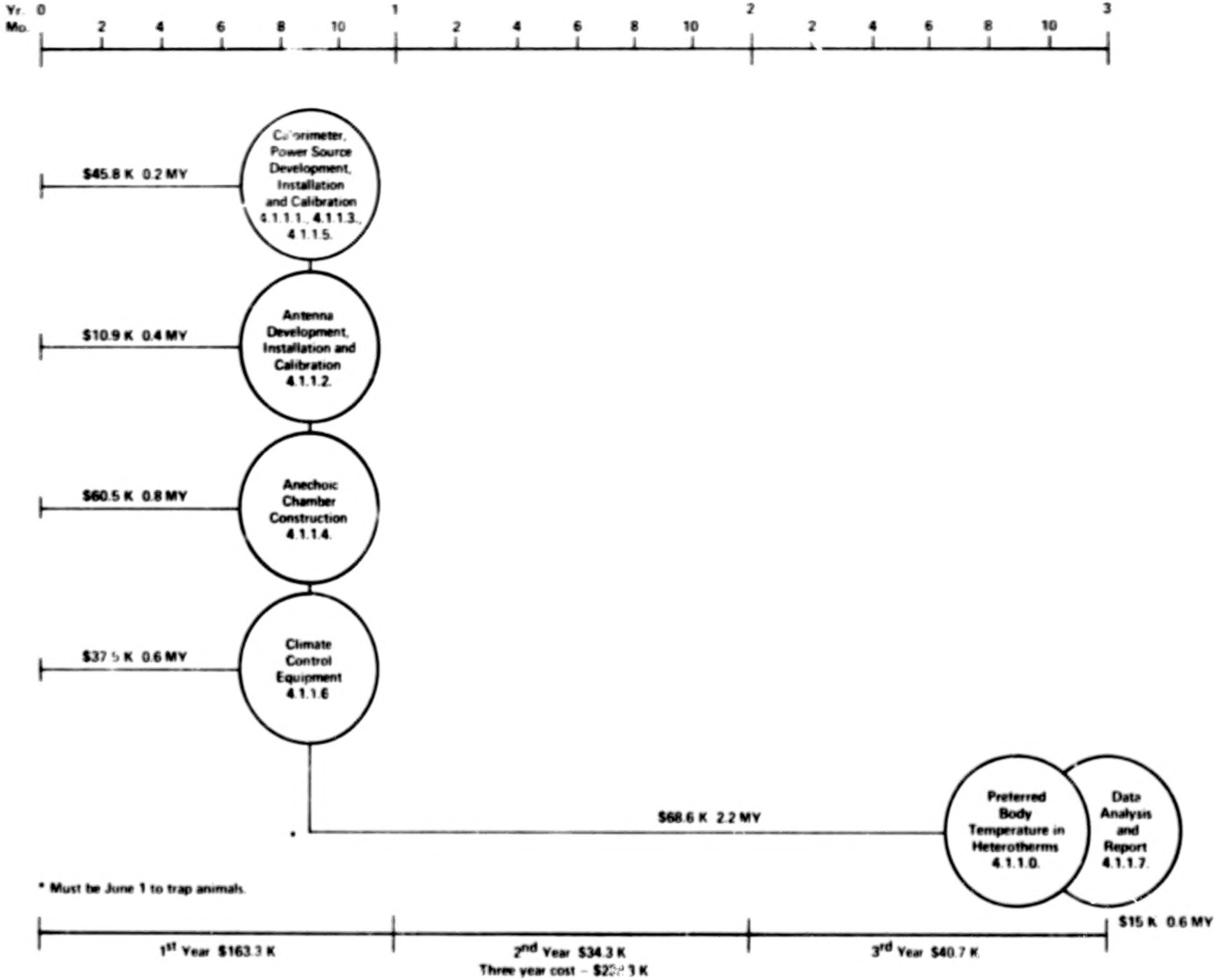

Figure 14

4.2 REPRODUCTION IN HETEROTHERMS

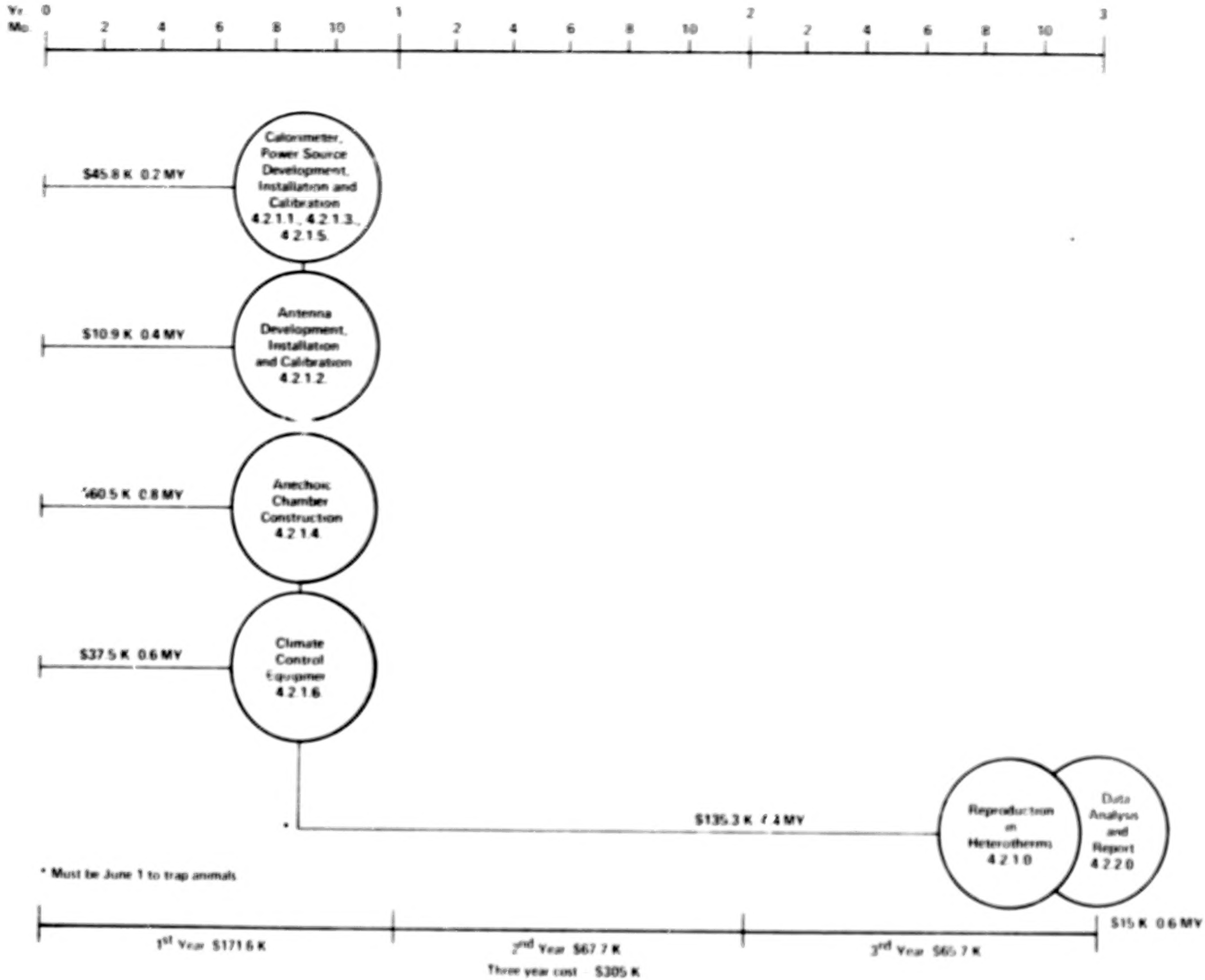

Figure 15

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PROTOCOLS

TABLE 65

4.1 MICROWAVE EFFECTS ON HETEROTHERMS

PROTOCOL 4.1.1.0 PREFERRED BODY TEMPERATURE IN LIZARDS

- HYPOTHESIS OR TASK: LIZARDS BEHAVIORLY THERMOREGULATE IN MICROWAVE FIELD. ANIMALS WILL SEEK A PREFERRED BODY TEMPERATURE IN A MICROWAVE FIELD. ACTIVITY PATTERNS UNDER MICROWAVE ILLUMINATION MAY DIFFER FROM THOSE UNDER NATURAL (FIELD) CONDITIONS AND/OR HEAT-LAMP CONDITIONS.
- APPROACH: ABSORBED DOSE WILL BE DETERMINED. ANIMALS WILL BE OBSERVED IN THE FIELD, UNDER HEAT LAMPS, AND UNDER CONTINUOUS MICROWAVE IRRADIATION. HEAT-LAMP CONDITIONS WILL APPROXIMATE FIELD CONDITIONS 14/10 LIGHT/DARK. CLOACAL TEMPERATURE WILL BE DETERMINED AS MEASURE OF PREFERRED TEMPERATURE. ACTIVITY WILL BE MONITORED VIA CLOSED CIRCUIT TV.
- INFORMATION TO BE DERIVED: LIZARDS CAN USE MICROWAVE ENERGY TO THERMOREGULATE. QUANTITATIVE POWER LEVELS FOR THERMOREGULATION WILL BE DETERMINED. AVOIDANCE OF AND/OR ATTRACTION FOR MICROWAVE FIELD WILL BE DETERMINED.
- EXPERIMENT TIME:
  - MONTHS TO COMPLETE: 24
  - MAN YEARS: 2.2
- COST FOR RESEARCH: $68.6K
- NEW FACILITIES REQUIRED:

	TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
4.1.1.1	5 kW, 2450 MHz POWER SOURCE	$17.7K	0.2	9 MONTHS
4.1.1.2	ANTENNA DEVELOPMENT	$10.9K	0.4	9 MONTHS
4.1.1.3	CALORIMETER AND RECORDER	$ 8.8K	---	9 MONTHS
4.1.1.4	ANECHOIC CHAMBER	$60.5K	0.8	9 MONTHS
4.1.1.5	POWER AND FREQUENCY MONITORS	$19.3K	0.2	9 MONTHS
4.1.1.6	CLIMATE CONTROL EQUIPMENT	$37.5K	0.6	9 MONTHS

TABLE 66

4.1 MICROWAVE EFFECTS ON HETEROTHERMS

PROTOCOL 4.1.2.0 ANALYSIS AND REPORT FOR 4.1.1.0

- HYPOTHESIS OR TASK: FROM THE RESULTS OF REPEATED MEASUREMENTS OF CLOACAL TEMPERATURE IN RELATION TO POWER LEVEL, ENVIRONMENTAL TEMPERATURE, AND HEAT-LAMP ENERGY, THE PREFERRED BODY TEMPERATURE WILL BE DETERMINED. ANALYSIS OF MARKED INDIVIDUALS VIA TV RECORDING WILL BE USED TO DETERMINE ACTIVITY PATTERNS.
- APPROACH: STATISTICAL ANALYSIS WILL BE USED TO ASCERTAIN THE VALUE OF THESE DATA. COMPARISON OF EACH SET OF CONDITIONS, EACH GROUP OF ANIMALS (REPLICATES), AND EACH OF SEVERAL SPECIES WILL BE MADE.
- INFORMATION TO BE DERIVED: FROM THE ANALYSIS INDICATED ABOVE, THE EFFECTS UPON THERMOREGULATION AND ACTIVITY OF EACH SPECIES SHOULD PROVIDE AN EVALUATION OF THE EFFECTS UPON HETEROTHERMS.
- EXPERIMENT TIME:

MONTHS TO COMPLETE	3
MAN YEARS	.6

- COST FOR RESEARCH: $15K
- NEW FACILITIES REQUIRED:

TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
COMMON WITH 4.1.1.0			

TABLE 67

4.2 REPRODUCTION IN HETEROTHERMS

PROTOCOL 4.2.1.0 REPRODUCTION OF HETEROTHERMS UNDER MICROWAVE ILLUMINATION

- HYPOTHESIS OR TASK: LIZARDS ARE NONMIGRATORY AND HAVE SMALL HOME RANGES, THUS MAY BE LIMITED TO AREAS CONTINUALLY ILLUMINATED BY MICROWAVE ENERGY. PRODUCTIVITY CHANGES AND/OR TERATOLOGY MAY APPEAR IN SUCH POPULATIONS.
- APPROACH: ANIMALS IN VARIOUS STAGES OF REPRODUCTION WILL BE IRRADIATED. OTHER GROUPS WILL BE ILLUMINATED DURING A COMPLETE GENERATION OR TWO REPRODUCTIVE EVENTS.
- INFORMATION TO BE DERIVED: SHORT EXPOSURES MAY REVEAL CHANGES IN CLUTCH SIZE, HATCHABILITY, AND TERATOLOGICAL EFFECTS IN THE OFFSPRING. LONG-TERM IRRADIATION MAY SHOW ALL OF THE ABOVE PLUS CHANGES IN THE POPULATION DYNAMICS OF THESE ANIMALS.
- EXPERIMENT TIME:
  - MONTHS TO COMPLETE: 24
  - MAN YEARS: 4.4
- COST FOR RESEARCH: $135.3K
- NEW FACILITIES REQUIRED:

	TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
4.2.1.1	5 κW, 2450 MHz POWER SOURCE	$17.7K	0.2	9 MONTHS
4.2.1.2	ANTENNA DEVELOPMENT	$10.9K	0.4	9 MONTHS
4.2.1.3	CALORIMETER & RECORDER	$ 8.8K	---	9 MONTHS
4.2.1.4	ANECHOIC CHAMBER	$60.5K	0.8	9 MONTHS
4.2.1.5	POWER AND FREQUENCY MONITORS	$19.3K	0.2	9 MONTHS
4.2.1.6	CLIMATE CONTROL EQUIPMENT	$37.5K	0.6	9 MONTHS

TABLE 68

4.2 REPRODUCTION IN HETEROTHERMS

PROTOCOL 4.2.2.0 ANALYSIS AND REPORT FOR 4.2.1.0

- o HYPOTHESIS OR TASK: PRODUCTIVITY OF ANIMAL EXPOSED WILL BE EVALUATED BY CLUTCH SIZE, NUMBER OF EGGS HATCHING PER CLUTCH, SIZE OF OFFSPRING AND WILL BE COMPARED TO LABORATORY CONTROL AND FIELD DATA. TERATOLOGY WILL BE EVALUATED ON A COMPARATIVE BASIS WITHIN AND AMONG THE SEVERAL GROUPS AND SPECIES.
- o APPROACH: STATISTICAL EVALUATION OF THESE DATA WILL BE USED TO COMPARE THE GROUPS, INDIVIDUALS, AND SPECIES.
- o INFORMATION TO BE DERIVED: THESE DATA AND THE ANALYSES SHOULD PROVIDE A BASE FOR EVALUATION OF THE EFFECTS THESE CONDITIONS MAY HAVE UPON POPULATION OF THESE SPECIES.
- o EXPERIMENT TIME:

MONTHS TO COMPLETE	3
MAN YEARS	.6

- o COST FOR RESEARCH: $15K
- o NEW FACILITIES REQUIRED:

TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
COMMON WITH 4.2.1.0			

MILESTONE AND FUNDING SUMMARY

TABLE 69

MILESTONE AND FUNDING SUMMARY

	PHASE A YEAR				COST $K		
	0	1	2	3	Exper.	Facil.	Question
4.1.0.0 Microwave Effects on the Behavior of Heterotherms				▽	--	---	238
4.1.1.0 Preferred Body Temperature in Lizards				▽	69	155	
4.1.2.0 Analysis and Report				▽	15	---	
4.2.0.0 Microwave Effects on the Reproduction in Heterotherms				▽	--	---	305
4.2.1.0 Reproduction of Heterotherms under Microwave Illumination				▽	135	155	
4.2.2.0 Analysis and Report				▽	15	---	

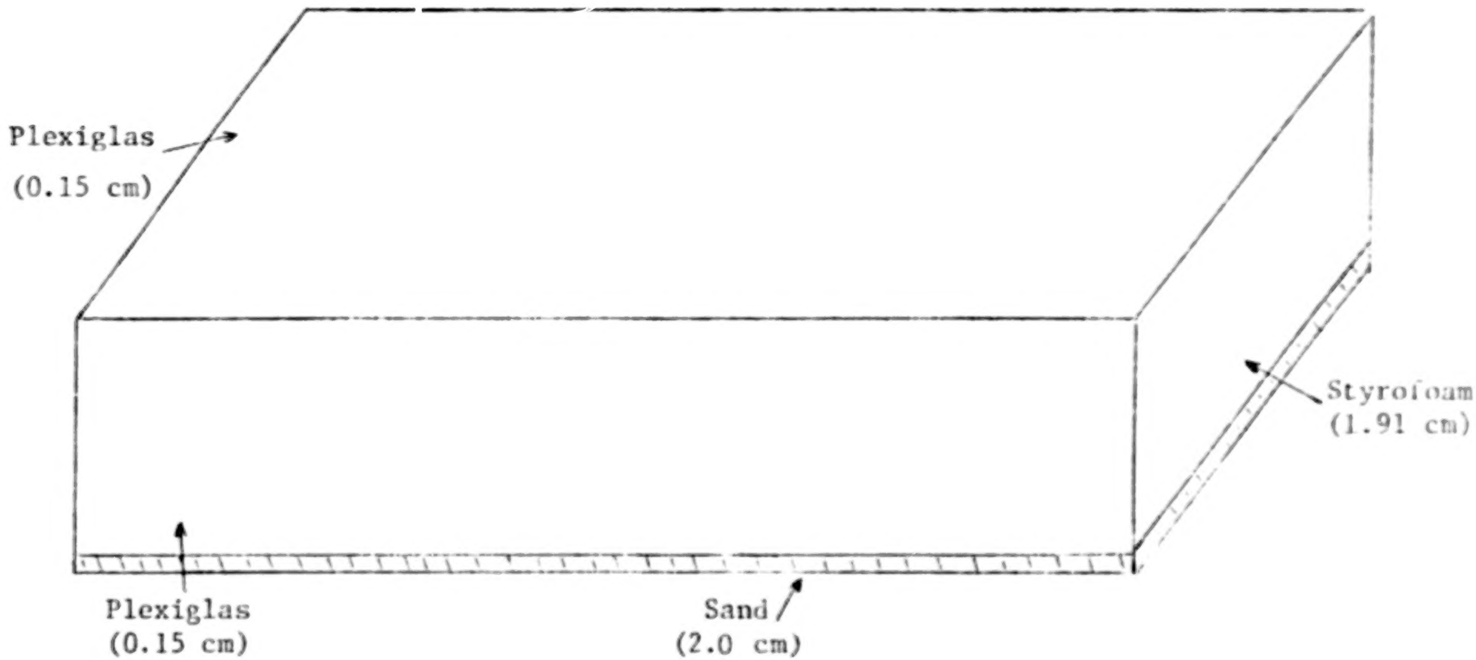
PILOT EXPERIMENTATION

Can lizards use microwave energy to thermoregulate a preferred body temperature?

In order to ask the question regarding microwave use in a preliminary fashion, animals were trapped, acclimated to the laboratory, and provided an infrared source (GE heat lamp on a 14-light/10-dark cycle) and observed. When the light is turned on, the animals begin to move and become active, spending most of the time "basking" under the lamp until their preferred temperature is attained. A box of the dimensions shown in Figure 16 was constructed and placed in an anechoic chamber and illuminated with a CW 2.45 GHz source. The average room temperature was 21° C. The box was filled with a 2.0 cm thick layer of fine sand. Measurements of power density within the styrofoam box at the level of the sand were made using a Nards 8100B field intensity probe. The numbers obtained for local field intensities are shown in Figure 17. A higher field intensity (such as 93 versus 50 mW/cm^2 at point A) is ascribed to sand-caused reflection. Field intensities considerably higher than these values are anticipated for wet sand, which was not used in these preliminary experiments. Six lizards of the species *Cnemidophorus tigris* were placed in the box and illuminated.

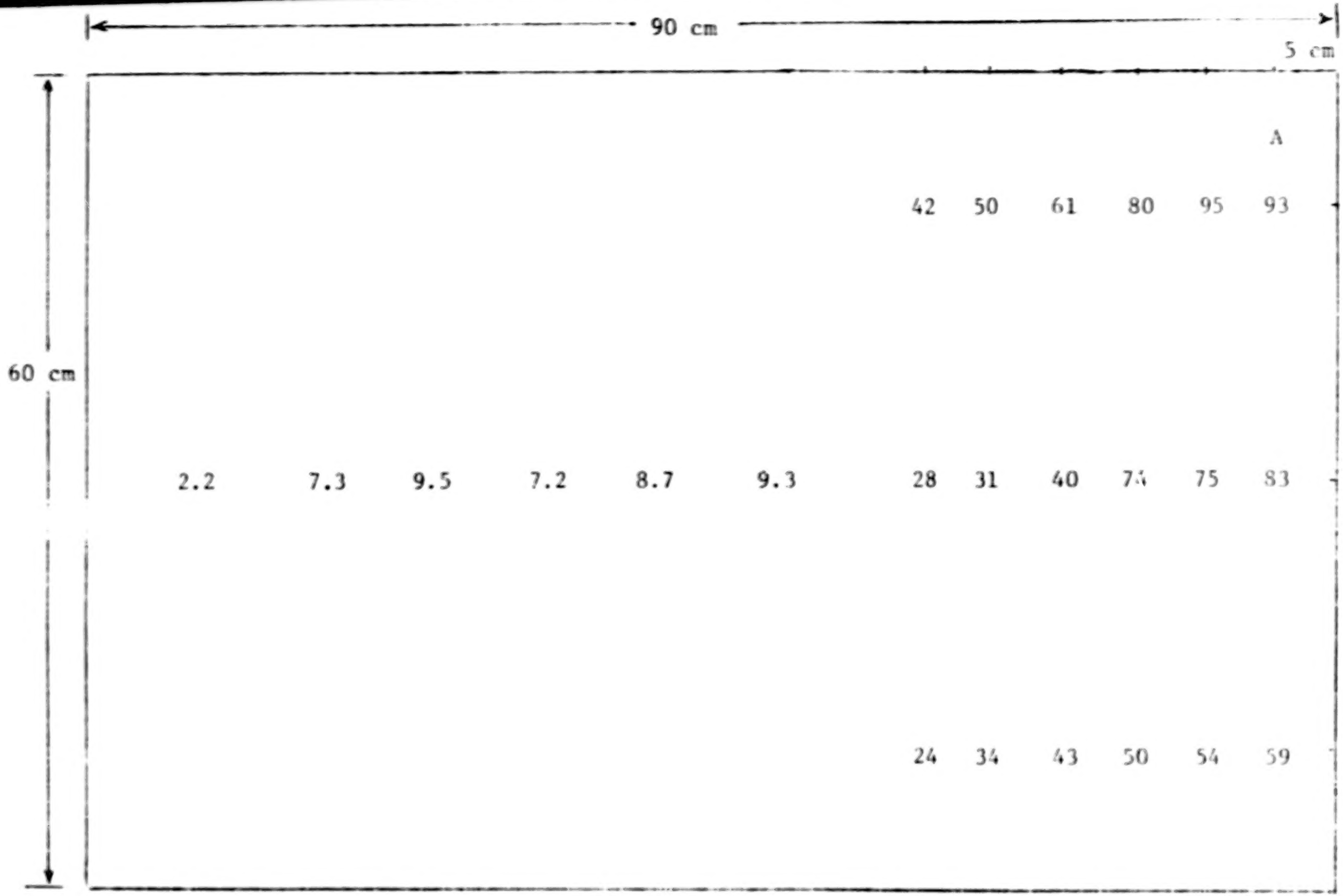
The activity of the lizards under these conditions was estimated by observation. An active lizard was defined as one exploring the box and/or moving toward or away from the source. The other or nonactive time was spent "basking" in the area of high power or incident electro-magnetic fields. There were differences in the level of activity and cloacal temperature under sun lamp and microwave illumination. The mean levels of activity during each one-half hour observation period and the mean cloacal temperature at the end of each observation period under both exposure conditions for six lizards are shown in Table 70.

Under sunlamp illumination, the animals regulate a mean cloacal temperature of 97.53° F, while under microwave exposure, mean cloacal temperature dropped to 94.32° F. Mean activity also dropped while the animals were illuminated with microwaves. An interesting observation showed that under microwave exposure, all lizards rested in the corner of the styrofoam shuttle box illuminated with the highest incident power density (50 mW/cm^2). Under sunlamp illumination, this basking by all six lizards in such close proximity was never seen. Mutual basking and decreased activity time of the animals in the microwave condition



Styrofoam and Plexiglas shuttle box for microwave illumination.

Figure 16



Power density distribution at sand level of the styrofoam shuttle box in mW/cm^2 (top view). Free-space incident field intensity at point A = 50 mW/cm^2.

Figure 17

TABLE 70

MEAN LEVEL OF ACTIVITY AND CLOACAL TEMPERATURE OF LIZARDS

EXPOSED TO SUNLAMP AND CW 2.45 GHz MICROWAVE ENERGY

Thirty-minute Observation Period	Sunlamp Illumination-Six Lizards			Microwave Illumination-Six Lizards		
	Average Minutes Active	Average Minutes Rest	Average Cloacal Temperature °F	Average Minutes Active	Average Minutes Rest	Average Cloacal Temperature °F
8-8:30 A.M.	10.17	19.83	97.42	6.00	24.00	92.75
10-10:30 A.M.	11.16	18.84	96.16	6.50	23.50	93.42
12-12:30 P.M.	8.16	21.83	98.00	11.66	18.34	93.50
2-2:30 P.M.	9.66	20.44	98.08	3.17	26.83	95.75
4-4:30 P.M.	7.16	22.84	98.00	0.0	30.00	96.17
Mean	9.26	20.74	97.53	5.47	24.53	94.32

may be due to several factors. Activity and cloacal temperatures under a combination of sunlamp and microwave illumination may give added insight. Answers for these questions, however, will require further experiments. Also, for future experiments, a larger depth of sand should be used. In the present experiment, the sand in the microwave high intensity area was routinely removed by burrowing of the animals, which may also have resulted in eliminating the reflection-caused enhancement of fields in corner A of the sandbox (Figure 16). Nevertheless, this experiment suggests that the whiptail lizard can detect and use microwave energy as an external heat source to regulate a somewhat constant body temperature above the ambient temperature.

In summary, lizards and snakes are nonmigratory; or if these do migrate, it is usually a seasonal move and is for relatively short distances. In particular, some lizards have very small home ranges, e.g., 40 m^2, and therefore, will be limited to areas under continuous illumination, i.e., near the edge of the rectenna. Using the approaches indicated, the effect upon teratology developmental, reproductive behavior, and population parameters can be ascertained.

Finally, based upon the results of the two studies included in the research plan, the effect of SPS microwave power on the activity, body temperature, reproduction, and population dynamics of heterotherms may be ascertained.

VII. EFFECTS OF CW 2.45 GHz MICROWAVES

ON INSECTS AND OTHER TERRESTRIAL INVERTEBRATES*

SIGNIFICANCE OF CATEGORY

Introduction and Background. - The relationship of power levels expected within the projected rectenna areas to potentially adverse environmental and biological effects needs to be determined for a broad spectrum of animal and plant life. Insect life is a very significant part of the environment. There are more species of insects than the combined total of all the other animal and plant species on earth. Insects have evolved complex interactions with essentially all plant and animal species that occupy terrestrial habitat niches.

In the plant kingdom, insects play a major role in controlling plant populations in several ways. Phytophagous insects utilize plants as food, consuming a significant portion of vegetation. In the process of feeding, many plant diseases are transmitted by insect vectors, and these pathogens affect plant populations, both in survival and reproductive potential. Insects also are vehicles for many non-pathogenic microorganisms that are dispersed in the environment, including the soil habitat. Some insects feed directly on plant seeds and can express a profound influence on plant reproduction. Many plants cannot reproduce without insect pollination, especially by bees. For example, honey bees provide an estimated 80% of the pollination of crops that ccount for approximately one-third of our total food production in the United States (20). One important relationship between insects and plants is that plants in a weakened condition frequently are far more susceptible to insect "attack". Complex physiological mechanisms often underly the plant defensive systems. The effects of insects on animal life are equally significant. Thousands of insect species are parasitic on larger animals, and predatory on smaller animals and microorganisms. Insects are probably the most important vectors of pathogens that can limit animal populations. Insects are a basic source of food for many animals, especially smaller species such as birds.

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*From Final Report for Ames Research Center, NASA Contract NAS2-9539, "Study of the Biological and Ecological Effects of Energy Transmission by Microwaves on Behavior of Insects and Other Terrestrial Invertebrates", Norman E. Gary and Becky J. Westerdahl, University of California at Davis, February 17, 1978

Subtle changes in the environment, such as those that conceivably may be caused by power levels found within rectenna areas, potentially could cause profound and perhaps unpredictable effects on the complex interactions between insects and other plants and animals. The net result could be great population fluctuations. For example, it is conceivable that insect prey-predator systems could be uncoupled, leading to massive population increases in some radiation tolerant species, which in turn could attract massive numbers of insectivorous birds on a regular or irregular basis.

In brief, short term and long term studies of insect survival and behavior are essential to evaluate the possible effects of microwave illumination.

Evaluation Strategies Using Insects as Test Organisms. - All potential rectenna locations for the Space Power Satellite (SPS) Program will contain numerous species of insects that are distributed in every conceivable habitat including the soil, on and within vegetation, inside crevices of trees and rocks, and flying actively or drifting passively through the air. Microwave effects on insects are likely to occur to some of the thousands of biochemicals that are a part of complex and delicately balanced physiological mechanisms in normal healthy organisms. Speculating on specific effects and developing specific assays to evaluate those changes is similar to searching for the proverbial needle in the haystack. Research on the effects of microwaves on vertebrates has shown that effects at low-levels of energy are more likely to be detected in behavioral responses and in the function of the central nervous system rather than microscopically or biochemically (21,22). Normal behavior is an expression of normal physiology. A single behavioral pattern reflects the normality of thousands of chemical reactions within the insect. Fortunately the behavior of insects offers an excellent tool for detecting significant changes in the physiology and biochemistry of individuals. Underlying mechanisms can be sought later if significant behavioral changes are detected. Insects, relative to higher animals, have a far simpler nervous system containing limited information storage capacity, thus favoring more stereotyped behavior. Complete patterns of behavior are programmed genetically and are expressed precisely in the same sequence and form in generation after generation of each species. Consequently, patterns of behavior are more predictable and can be characterized more accurately than in higher animals where changes through learning introduce much greater variation. Consequently, insect behavior is relatively easy to quantify and provides an excellent means for determining the effects of nonionizing electromagnetic energy on insect life.

The Honey Bee as a Test Organism. - Because there are more than one million species of insects, it is impractical to study even a small percentage of these species. However, the similar physiological and biochemical characteristics of various insect species makes it probable that significant effects of microwave illumination can be detected by studying only a few species. The honey bee probably is the most convenient, efficient, and economical species to use because:

1. Honey bees have been studied very intensively, perhaps more than any other single insect species. Great emphasis has been placed on behavioral studies. In particular, their sophisticated communication system has been studied in great depth by such outstanding scientists as Karl von Frisch (23,24), who shared the Nobel Prize for Medicine in 1973, primarily because of his bee communication studies. Subtle behavioral changes induced by microwave illumination, which could go unnoticed in insect species that are less active and not studied extensively, should be highly evident in honey bees.

2. Honey bee colonies, whether feral or domesticated, probably will be found at potential rectenna sites because honey bees are ubiquitous. Bees are more likely than other insects to fly through and forage in radiation areas because they routinely forage up to 8 km (25) from their colonies. An extreme flight range of 14.5 km has been reported (26).

3. Honey bees approximate the average size of all insects and are, therefore, a good representative test species, because energy absorption is related to size and wave length.

4. They are sensitive to various frequencies of the electro-magnetic spectrum, and their behavior can be affected by nonionizing energy (27,28,29,30,31,32,33).

5. They are economical and, if necessary, expendable. Approximately 3.6 by 10^5 kg (four hundred tons) of living worker bees are produced and exported commercially each year from California alone, so it is easy to obtain large quantities of bees quickly at approximately $11/kg (ca 7,800 bees).

6. Honey bees can be used for both laboratory and field experiments.

7. They are easily propagated and managed.

8. Colonies (hives) can be transported and placed strategically in field test areas.

9. Activities in the colonies and in the field can be manipulated for controlled exposures to microwave energy, so that behavior can be assessed before, during, and after exposure.

10. Honey bees are active in some parts of the country most of the year (e.g. in California), and diurnal activities, such as foraging, are relatively continuous.

11. Honey bees have a well developed time sense and various activities are governed by circadian rhythms that have been studied extensively (34,35).

12. Genetically identical stocks can be easily maintained for use in experiments.

<u>Other Representative Insects.</u> - The particular species of insects found within the rectenna areas will be highly dependent on the locations and on the animals and plants which are deemed by other investigators to be suitable to live there. All potential terrestrial locations for the rectenna sites will contain numerous species of insects because there is no known terrestrial habitat without insects.

Based on information currently available on the effects of microwaves on animals (most of which concerns vertebrates), and on current knowledge of insect behavior, the following criteria have been established to identify those insects in which microwave effects are most likely to be detected.

1. Microwave effects will be most easily detected in those insects which have a great variety of highly sterotyped behavioral patterns expressed with high frequency. Social insects and honey bees in particular, satisfy these criteria.

2. Insects that fly are more likely than nonflying insects to travel into and to be exposed to microwave illumination in the rectenna area.

3. Insects which are commonly found in exposed positions (such as on vegetation) are more likely to be affected by microwave illumination than those which live underground or within plant tissue.

4. Those insects which appear to be of a greater ecological and economical importance (e.g. pollinators, beneficial or harmful insects) should receive greater emphasis.

The more than one million species of insects have been grouped (based on similarities with respect to anatomy, morphology, evolutionary and behavioral development etc.) into 26 orders (27 if mites and ticks are included). Based on the total number of the above criteria (4,3,2,1, or 0) that each order possesses, the 27 orders can be divided into five groups in terms of the degree to which one may expect them to exhibit microwave effects and to have significant effects on other animals and plants living within the rectenna areas.

<u>GROUP 1:</u>

Hymenoptera - bees, ants, wasps

<u>GROUP 2:</u>

Coleoptera - beetles

Diptera - true flies

Lepidoptera - butterflies, moths

Hemiptera - true bugs

Thysanoptera - thrips

Isoptera - termites

Orthoptera - grasshoppers

Odonata - dragonflies

Acarina - mites and ticks

<u>GROUP 3:</u>

Siphonaptera - fleas

Trichoptera - caddisflies

Necoptera - scorpion flies

Neuroptera - lace wings

Anoplura - sucking lice

Mallophaga - chewing lice

Plecoptera - stoneflies

Ephemeroptera - may flies

<u>GROUP 4:</u>

Psocoptera - booklice

Dermaptera - earwigs

Thysanura - silverfish

Collembola - spring tails

<u>GROUP 5:</u>

Zoraptera - zorapterans

Embioptera - web spinners

Entrophi - campodeids

Protura - proturans

Strepsiptera - twisted-wing parasites

Studies of the effects of microwaves on insects other than honey bees should concentrate on those insects in Groups 1 and 2, because insects in these groups seem most likely to exhibit microwave effects and to have the greatest potential for ecological and economic impact within rectennal sites.

If studies are conducted on one representative insect species from each order in Group 2, and combined with detailed behavioral studies of the honey bee, an excellent overall view of the effects of microwaves on insect life should be obtained. This would enable studies on those insects actually found within the rectenna area to proceed much more rapidly after the rectenna location is determined and the species of animals and plants at that location are known.

Insects in Groups 3-5 do not appear to be as significant in terms of ecological importance at this time as Groups 1 and 2, yet, they are likely to be found within the rectenna area and may also require study as more information on the effects of microwave illumination on insect life becomes available.

In addition to the insects or Class *Insecta*, the *Arachnoidea* is included in the phylum *Arthropoda*. These are the spiders and scorpions that can be expected to be present in some rectenna sites. Other Classes in the *Arthropoda* are the *Chilopoda* - centipedes and the *Diplopoda* - millipedes. Invertebrates of other phylum, the *Nemathelminths* or roundworms and the *Annelida* - earthworms are sure to be present. Snails and slugs from the phylum *Mollusca*, Class *Gastropoda*, are other invertebrates that play a role in the ecology of most areas.

Status of Research on the Effects of Nonionizing Electromagnetic Energy on Arthropods and Other Invertebrates.- A variety of effects caused by exposure of insects to nonionizing radiation have been reported in the literature. According to Marha et al. (36), insects exposed to nonionizing radiation react similarly to mammals. The first symptom is unrest, "attempts" to escape, disturbance of motor coordination, stiffening, immobility, and then death (37,38). Marha also reports that changes in the concentration of a great variety of metabolic products has been found and that nonionizing radiation appears to affect embryo-genesis. Also, the time needed to complete morphogenesis in butterflies is increased and the life cycle and cocoon production of the mulberry boring beetle is accelerated (36).

Studies conducted by Greenberg (39,40,41,42), with low frequency radiation of 45, 60, and 75 Hz at levels up to 2500 millivolts/meter at 45 and 60 Hz and up to 910 millivolts/meter at 75 Hz on three orders of mites and on collembolans, found no significant differences in population levels between treated and control plots over a three year period. Also, no significant differences in oxygen consumption or respiratory quotient between exposed and control animals were found in studies using wood lice, earthworms, slugs, and salamanders.

Effects caused by nonionizing electromagnetic energy have been reported in honey bee colonies placed under high voltage transmission lines or exposed to alternating current electric fields (27,28,29,30,31,32,33). Bees in these colonies appeared "restless" and irritable. They frequently attacked and stung each other to death. There was apparent brood mortality at lower field strengths and brood was cast out of the colonies at higher field amplitudes. Honey and pollen were no longer stored and cells which had been filled with honey were emptied. After a few days of exposure, the colonies reportedly closed all the holes in the hive with propolis and died.

Frings (43) tested 14 species of insects, including adult worker honey bees, and found that insects may be killed by placing them in electromagnetic fields of 3 to 27 MHz at power levels ranging from 500 to 2000 volts/cm. The main cause of death was heating. The legs became heated long before the rest of the body and acted as conductors of heat to the rest of the body.

Studies have shown that CW 2.45 GHz microwaves at power levels of several hundred watts can kill a variety of insects such as the stored grain pests *Tribolium confusum*, *Sitophilus granarius*, and *Cryptoleates ferrugineus* (44,45), the eggs of the southern corn rootworm, *Diabrotica undecimpunctata howardi* (46), and all stages of cigarette beetles and tobacco moths (47). The effects of conventional heating through the same temperature range reportedly produced lower mortality of the treated species.

Studies by several investigators (48,49,50) using the pupae of the darkling ground beetle *Tenebrio molitor* conducted at 9 and 10 GHz caused an increased incidence of abnormal development at power levels below 10 mW/cm^2.

Aberrant growth responses following chronic exposure to 3.1 and 4.2 volts/cm at 60 Hz have also been reported in *Dugesia* (flatworms) (51).

Searle et al (52), conducted studies at CW 2.45 GHz on the larvae of the fruit fly *Drosophilia melanogaster*. When larvae were exposed to power densities as high as 1.0 W/cm^2, they found that growth rates during illumination were not significantly different from control values as long as heat was dissipated.

Zalyubovskaya (53) found that prolonged exposure of adult male and female *Drosophilia* for 3, 4, and 5 hours at a wavelength of 6.5 mm caused genetic changes that were manifested in lowered fertility and viability of the offspring. Mutation occurred frequently in the progeny of irradiated flies.

The exposure time necessary for a lethal reaction apparently can vary between different races of the same species. In *Drosophilia*, for example, some temperate species reportedly survive over 30 minutes (exposure level and frequency not specified) while tropical species lasted only a few seconds at the same field intensity. This effect did not appear to be purely thermal because when the illumination was replaced by an increase in temperature, the sensitivity of the two species was reversed (36).

These literature reports cited above indicate that nonionizing radiation produces a number of effects in a variety of invertebrates. High power levels cause the death of a large variety of invertebrates, primarily by an increase in temperature. Lower power levels have been shown to cause a variety of effects such as altered behavioral patterns, genetic mutations, teratological reactions and changes in development time. Research to date has shown that these effects appear to be more pronounced in those insects, such as the honey bee, which are more highly evolved, and which have a great variety of highly sterotyped behavioral patterns expressed with high frequency.

It is clear from the sparsity of data, marginal reproducibility of some investigations, and poorly defined treatment conditions, that much more research needs to be done before the effects of nonionizing radiation on insects can be determined accurately.

Even though vertebrates form a relatively small part of the animal kingdom, relative to invertebrates (5% vs. 95%), in terms of numbers of individuals and numbers of species, more than 10 times as many studies have been conducted on the effects of microwave energy on vertebrates as on invertebrates. Until recently, mans' concern has been with the possible biological effects of nonionizing radiation on humans. A variety of

vertebrates were used on the assumption that the results could be extrapolated to humans.

Although vertebrates have some advantages over insects as human surrogates, insects are good representative test species for the animal kingdom. They are similar to higher (and lower) animals with respect to many biochemical, physiological, and behavioral characteristics. Other advantages are their small size, relative simplicity of various body systems, ease and inexpensiveness of propagation, expendability, and short life cycle. Studies using insects (relative to higher animals) can be conducted on larger numbers of individuals much more rapidly and with a higher degree of reproducibility. In particular, chronic studies involving exposure of successive generations can be completed much more rapidly with insects than with vertebrates.

PRIORITIZED LIST OF QUESTIONS

1. WILL CW 2.45 GHz MICROWAVE ILLUMINATION AFFECT THE FORAGING BEHAVIOR OF HONEY BEES?

Since it is not possible to study all or even a small percentage of more than one million species of insects, detailed studies will be conducted on one representative insect (the honey bee).

The foraging and intra-colony behavior of honey bees are closely interrelated. If significant microwave effects occur to either one, disturbances in the other are likely to occur. However, the study of microwave effects on foraging behavior has more significance for the success of the SPS program, as bees forage up to 14.5 km from their colonies. Unlike other animals, they cannot be confined by conventional barriors. If significant microwave effects occur to honey bees or other insects that travel great distances during foraging or migrations, the safety margins surrounding rectennae would have to extend for considerable distances. In addition, crops requiring honey bees or other insects for pollination could not be grown within, or perhaps near, rectennal areas.

Normal foraging behavior is essential to the life of a honey bee colony as it is the means by which food is collected to sustain the colony.

2. WILL CW 2.45 GHz MICROWAVE ILLUMINATION AFFECT THE BIOLOGY AND INTRA-COLONY BEHAVIOR OF HONEY BEES?

If microwave illumination has significant effects on the biology and intra-colony behavior of honey bees, then colonies cannot be placed within rectennae. If microwave illumination affects the behavior of honey bees, then it is likely to affect the behavior of many other insect species as well. Both foraging and intra-colony behavior must be studied, as it is possible that microwaves may not affect the behavior of individual foraging bees, but may affect patterns of group behavior that occur within the hive.

3. WILL CW 2.45 GHz MICROWAVE ILLUMINATION AFFECT THE BIOLOGY AND BEHAVIOR OF OTHER REPRESENTATIVE INSECTS?

Although the detailed study of all aspects of the behavior of one representative insect (the honey bee) is necessary, it is also important to study the effects of microwaves on the biology and behavior of representative insects from those other orders most likely to be affected by microwaves and most likely to be found within rectennae. This is because differences are likely to occur between different orders of insects, caused by differences in morphology, anatomy, physiology, ecology and behavior.

4. WILL CW 2.45 GHz MICROWAVE ILLUMINATION AFFECT INVERTEBRATES OTHER THAN THE *ARTHROPODA* IN A SIMILAR MANNER TO INSECTS?

Many other invertebrates will inhabit the rectenna area, that exist near the surface or on foliage. These include the *Nemathelminths*, which are the most prolific of worms, the roundworms; the *Annelida* or earthworms, and the slugs and snails that belong to the Class *Gastropoda*. All play a role in the ecological balance and some can be highly destructive to plant life and cause illness in livestock.

PLANNING CHARTS

5.0.0.0. INSECTS

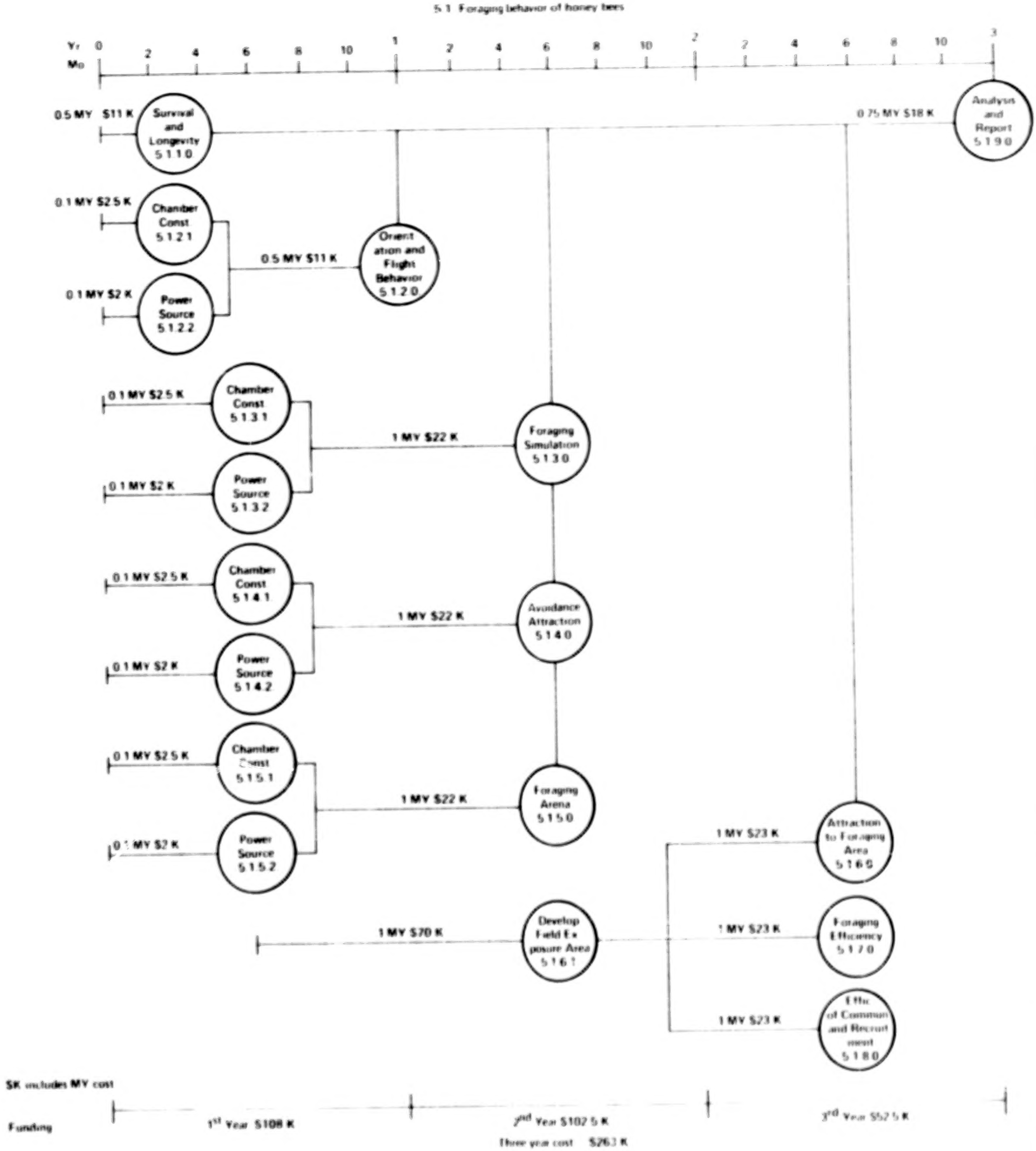

Figure 18

5000 INSECTS

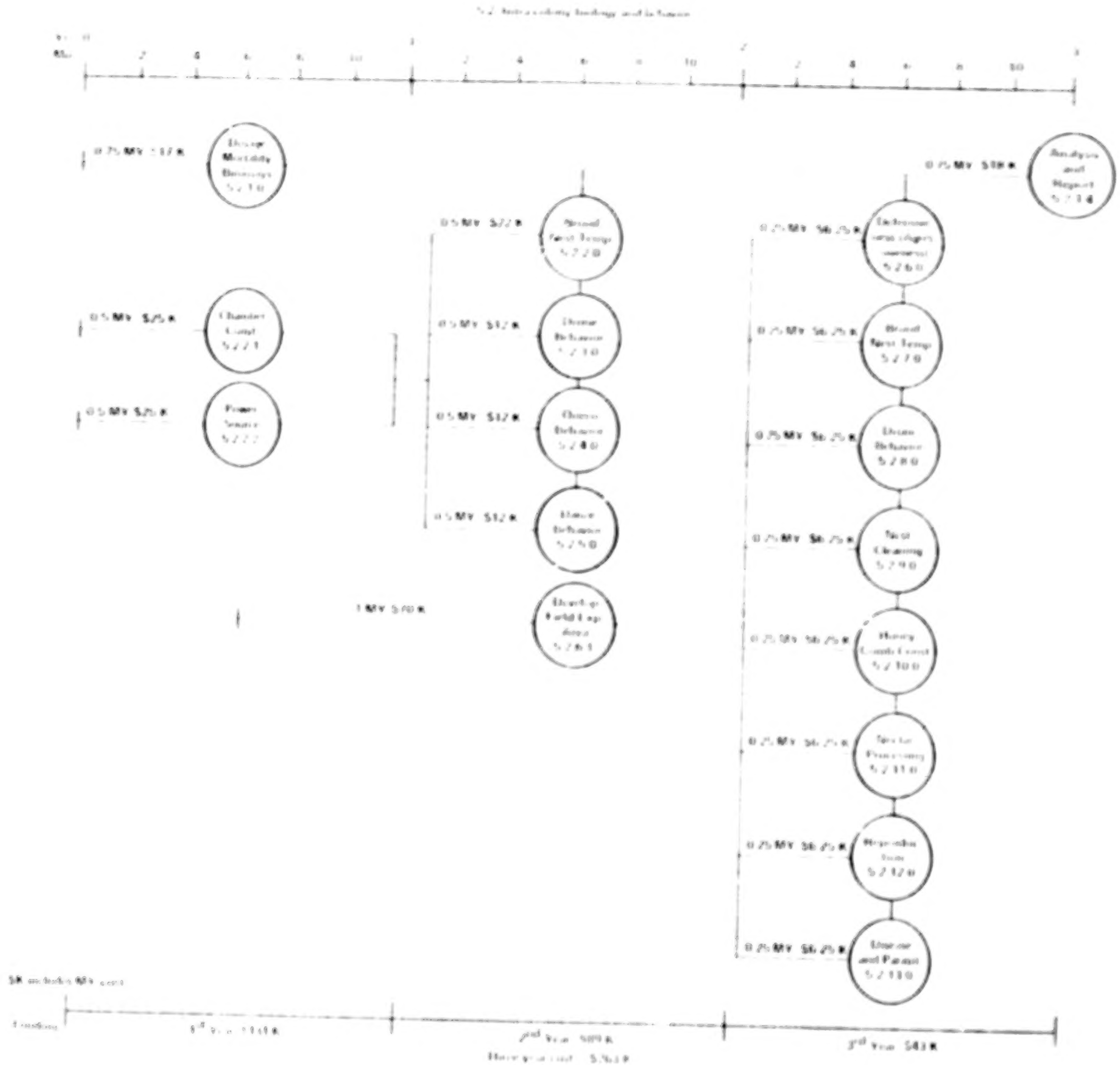

Figure 19

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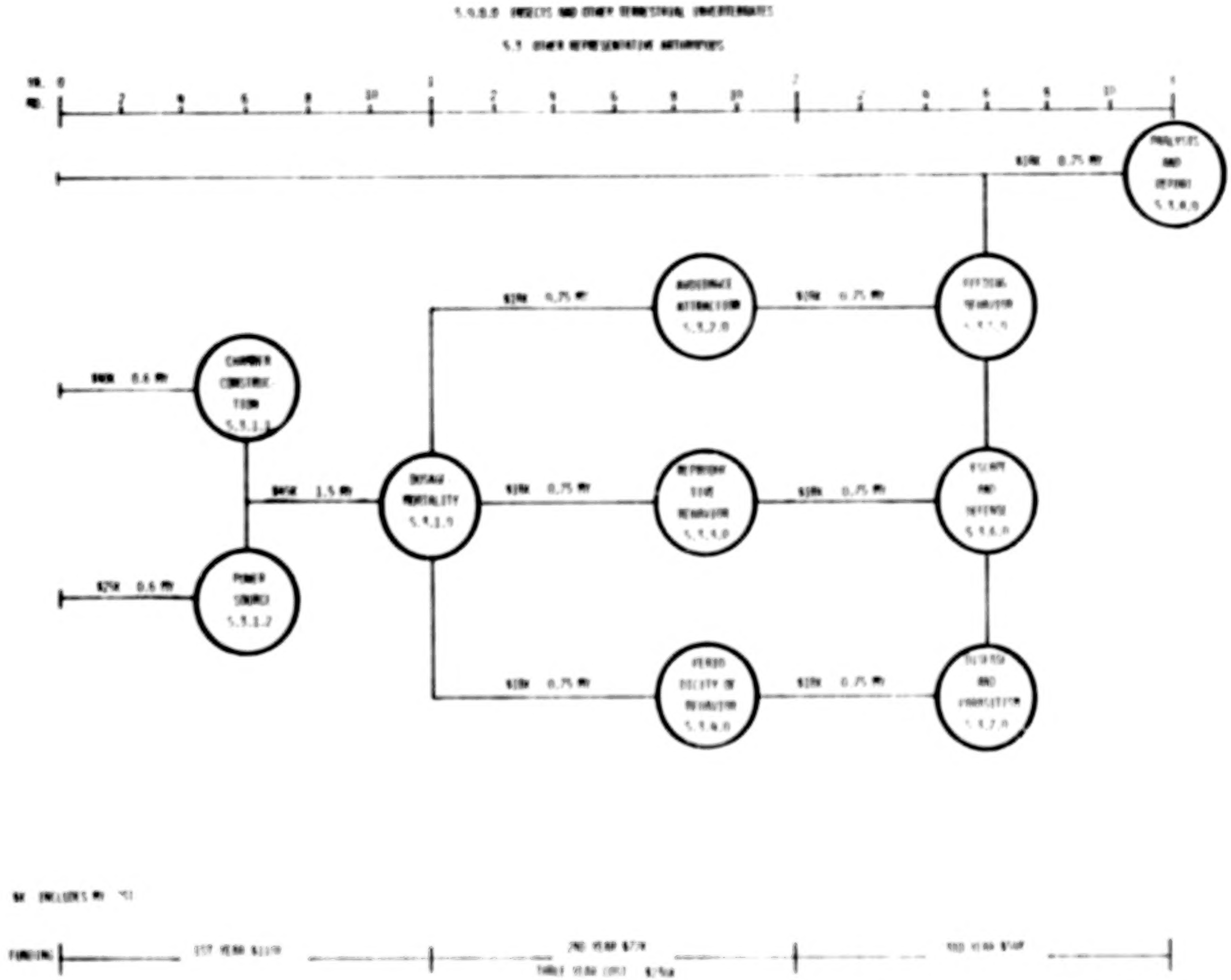

Figure 20

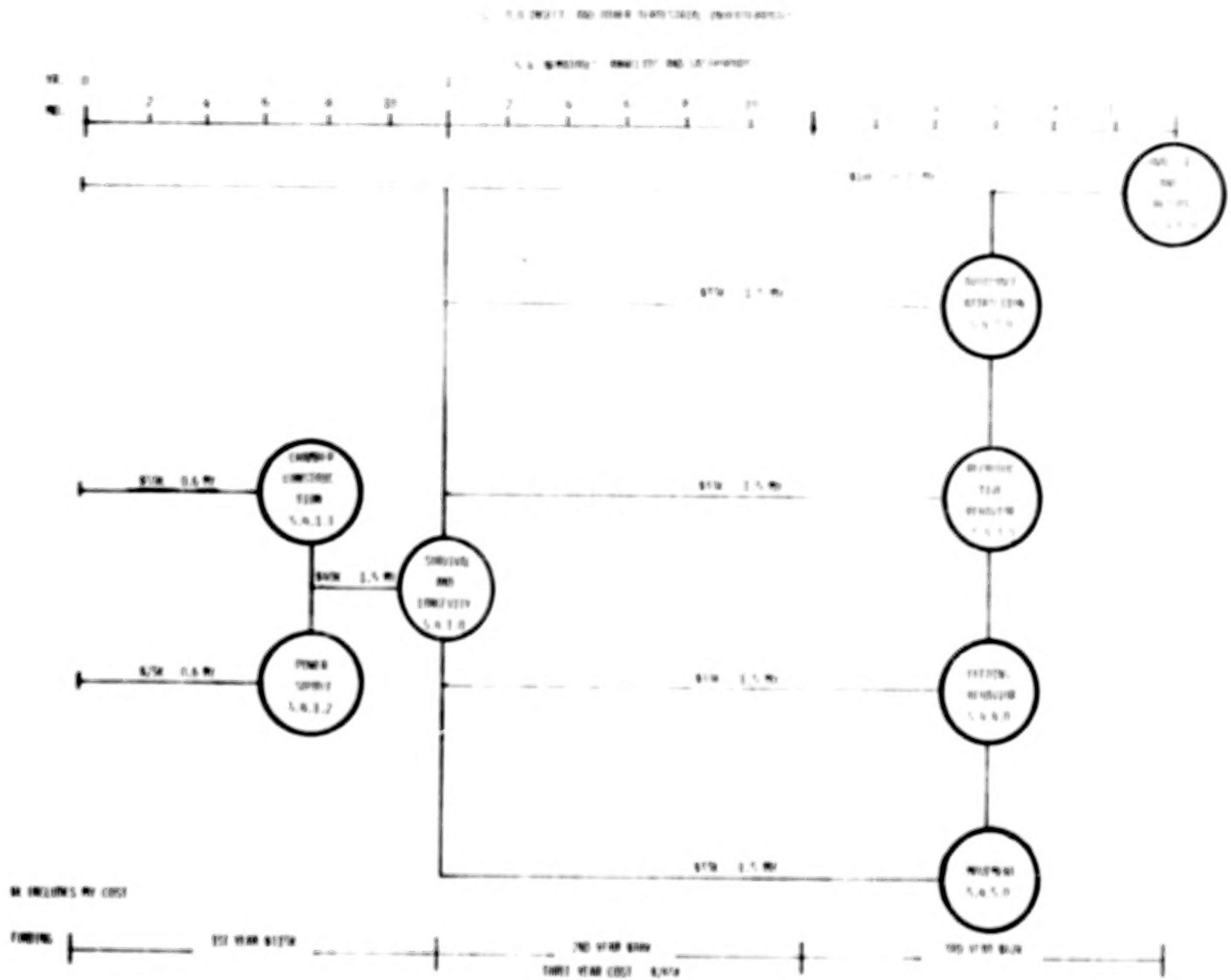

Figure 21

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PROTOCOLS

TABLE 71

5.1 EFFECTS OF 2.45 GHz CW MICROWAVE ILLUMINATION ON FORAGING BEHAVIOR OF HONEY BEES

PROTOCOL 5.1.1.0 SURVIVAL AND LONGEVITY

- o HYPOTHESIS OR TASK: CONDUCT DOSAGE-MORTALITY BIOASSAYS ON ADULT WORKER BEES TO DETERMINE THE RANGE OF EXPOSURES TO BE USED IN BEHAVIORAL EXPERIMENTS.
- o APPROACH: INDIVIDUALS AND GROUPS OF ADULT WORKER BEES WILL BE EXPOSED TO VARIOUS TREATMENTS IN WHICH LEVELS OF ILLUMINATION AND TIME OF EXPOSURE ARE MAJOR VARIABLES. POST-EXPOSURE SURVIVAL WILL BE DETERMINED.
- o INFORMATION TO BE DERIVED: THE SURVIVAL LIMITS OF ADULT WORKER BEES AND THE RANGE OF EXPOSURE LEVELS TO BE USED IN BEHAVIORAL STUDIES WILL BE DETERMINED.
- o EXPERIMENT TIME:

MONTHS TO COMPLETE	3
MAN YEARS	.5

- o COST FOR RESEARCH: $11K
- o NEW FACILITIES REQUIRED:

TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
NONE			

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TABLE 72

5.1 EFFECTS OF 2.45 GHz CW MICROWAVE ILLUMINATION ON FORAGING BEHAVIOR OF HONEY BEES

<u>PROTOCOL 5.1.2.0 ORIENTATION AND FLIGHT BEHAVIOR</u>

- o <u>HYPOTHESIS OR TASK</u>: MICROWAVE ILLUMINATION WILL AFFECT ORIENTATION AND FLIGHT BEHAVIOR OF BEES THAT FORAGE IN MICROWAVE ILLUMINATED AREAS.
- o <u>APPROACH</u>: PRE-EXPOSURE BEHAVIOR OF TAGGED NECTAR, POLLEN AND WATER FORAGERS WILL BE EVALUATED BY SEVERAL PARAMETERS. THE TAGGED BEES WILL THEN BE CAPTURED AND EXPOSED IN THE LABORATORY. AFTER EXPOSURE, THE BEES WILL BE RELEASED AND THEIR BEHAVIOR COMPARED WITH PRE-EXPOSURE DATA.
- o <u>INFORMATION TO BE DERIVED</u>: DETERMINATION OF POSSIBLE EFFECTS OF MICROWAVE EXPOSURE TO BEES FLYING IN ILLUMINATED AREA.
- o <u>EXPERIMENT TIME</u>:

MONTHS TO COMPLETE	9
MAN YEARS	.5

- o <u>COST FOR RESEARCH</u>: $11K
- o <u>NEW FACILITIES REQUIRED</u>:

	TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
5.1.2.1	CHAMBER	$2.5K	.1	3 MONTHS
5.1.2.2	POWER SOURCE	$2K	.1	3 MONTHS

TABLE 73

5.1 EFFECTS OF 2.45 GHz CW MICROWAVE ILLUMINATION ON FORAGING BEHAVIOR OF HONEY BEES

PROTOCOL 5.1.3.0 FORAGING SIMULATION

- HYPOTHESIS OR TASK: MICROWAVE ILLUMINATION WILL AFFECT THE FORAGING BEHAVIOR OF HONEY BEES THAT LIVE OUTSIDE AND FORAGE INSIDE ILLUMINATED AREAS.
- APPROACH: BEHAVIORAL PARAMETERS OF TAGGED BEES TRAINED TO FORAGE AT FEEDERS WHICH CAN BE TREATED WITH MICROWAVE ILLUMINATION WILL BE MEASURED PRIOR TO EXPOSURE. BEES WILL THEN BE GIVEN A CHOICE OF FORAGING AT FEEDERS EXPOSED TO VARIOUS LEVELS OF ENERGY FOR VARIOUS LENGTHS OF TIME. BEHAVIOR DURING AND AFTER EXPOSURE WILL BE EVALUATED AS IT WAS PRIOR TO EXPOSURE.
- INFORMATION TO BE DERIVED: DETERMINATION OF POSSIBLE SHORT TERM EFFECTS ON BEES FORAGING IN ILLUMINATED AREAS.
- EXPERIMENT TIME:
  - MONTHS TO COMPLETE: 12
  - MAN YEARS: 1
- COST FOR RESEARCH: $22K
- NEW FACILITIES REQUIRED:

	TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
5.1.3.1	CHAMBER	$2.5K	.1	6 MONTHS
5.1.3.2	POWER SOURCE	$2.K	.1	6 MONTHS

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TABLE 74

5.1 EFFECTS OF 2.45 GHz CW MICROWAVE ILLUMINATION ON FORAGING BEHAVIOR OF HONEY BEES

PROTOCOL 5.1.4.0 AVOIDANCE-ATTRACTION

- o HYPOTHESIS OR TASK: HONEY BEES CAN SENSE MICROWAVE ENERGY AND RESPOND SIMILARLY TO OTHER EXOGENOUS STIMULI.
- o APPROACH: DETERMINE THE RESPONSE THRESHOLD FOR AVOIDANCE OR ATTRACTION. DETERMINE IF ADAPTATION AND/OR HABITUATION OCCURS. IF SO, BEES WILL BE EXPOSED TO MICROWAVES AFTER VARIOUS LENGTHS OF RECOVERY TIME TO TEST FOR RESTORATION OF SENSITIVITY.
- o INFORMATION TO BE DERIVED: THIS STUDY WILL DETERMINE (A) IF HONEY BEES CAN SENSE MICROWAVE FIELDS, (B) IF SENSORY ADAPTATION TO THE FIELD OCCURS, (C) IF THEY CAN RESPOND ADAPTIVELY, AND (D) IF RESTORATION OF SENSITIVITY OCCURS RAPIDLY.
- o EXPERIMENT TIME:

MONTHS TO COMPLETE	12
MAN YEARS	1

- o COST FOR RESEARCH: $22K
- o NEW FACILITIES REQUIRED:

	TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
5.1.4.1	CHAMBER	$2.5K	.1	6 MONTHS
5.1.4.2	POWER SOURCE	$2K	.1	6 MONTHS

TABLE 75

5.1 EFFECTS OF 2.45 GHz CW MICROWAVE ILLUMINATION ON FORAGING BEHAVIOR OF HONE. .

PROTOCOL 5.1.5.0 FORAGING ARENA

- o HYPOTHESIS OR TASK: IDENTIFY FORAGING BEHAVIORAL PATTERNS THAT ARE LIKELY TO BE AFFECTED BY MICROWAVE ILLUMINATION.
- o APPROACH: VARIOUS PARAMETERS OF FORAGING BEHAVIOR WILL BE STUDIED IN A LABORATORY FORAGING ARENA CONNECTED TO AN OBSERVATION HIVE.
- o INFORMATION TO BE DERIVED: ELEMENTS OF FIELD FORAGING BEHAVIOR THAT ARE LIKELY TO BE DISTURBED BY MICROWAVE EXPOSURE WILL BE DETERMINED UNDER CONTROLLED CONDITIONS THAT OPTIMIZE EVALUATION.
- o EXPERIMENT TIME:

MONTHS TO COMPLETE	12
MAN YEARS	1

- o COST FOR RESEARCH: $22K
- o NEW FACILITIES REQUIRED:

	TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
5.1.5.1	CHAMBER	$2.5K	.1	6 MONTHS
5.1.5.2	POWER SOURCE	$2K	.1	6 MONTHS

TABLE 76

5.1 EFFECTS OF 2.45 GHz CW MICROWAVE ILLUMINATION ON FORAGING BEHAVIOR OF HONEY BEES

<u>PROTOCOL 5.1.6.0 ATTRACTION TO FORAGING AREA</u>

- <u>HYPOTHESIS OR TASK</u>: CHRONIC MICROWAVE EXPOSURE WILL ALTER THE ATTRACTIVENESS OF FORAGING AREAS TO HONEY BEES.
- <u>APPROACH</u>: THE FORAGING ACTIVITY OF BEES WILL BE DETERMINED AT CONTROLLED FORAGING AREAS THAT ARE EITHER TREATED OR NOT TREATED WITH MICROWAVE ILLUMINATION.
- <u>INFORMATION TO BE DERIVED</u>: THE EFFECTS OF MICROWAVE ILLUMINATION ON THE DISTRIBUTION AND FORAGING BEHAVIOR OF BEES WILL BE DETERMINED.
- <u>EXPERIMENT TIME</u>:

MONTHS TO COMPLETE	12
MAN YEARS	1

- <u>COST FOR RESEARCH</u>: $23K
- <u>NEW FACILITIES REQUIRED</u>:

	TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
5.1.6.1	FIELD EXPOSURE AREA	$70K	1	1 YEAR

TABLE 77

5.1 EFFECTS OF 2.45 GHz CW MICROWAVE ILLUMINATION ON FORAGING BEHAVIOR OF HONEY BEES

PROTOCOL 5.1.7.0 FORAGING EFFICIENCY

- HYPOTHESIS OR TASK: CHRONIC MICROWAVE ILLUMINATION WILL AFFECT THE FORAGING EFFICIENCY OF HONEY BEES.
- APPROACH: THE FORAGING EFFICIENCY (FOOD ACQUIRED PER UNIT TIME) OF INDIVIDUAL BEES AND OF COLONIES WILL BE DETERMINED UNDER CONDITIONS WHEN (A) ONLY THE COLONY IS TREATED, (B) ONLY THE FORAGING AREA IS TREATED, AND (C) BOTH COLONY AND FORAGING AREA ARE TREATED.
- INFORMATION TO BE DERIVED: THE EFFECTS OF MICROWAVE ILLUMINATION ON THE EFFICIENCY OF FORAGING WILL BE DETERMINED.
- EXPERIMENT TIME:

MONTHS TO COMPLETE	12
MAN YEARS	1

- COST FOR RESEARCH: $23K
- NEW FACILITIES REQUIRED:

TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
COMMON WITH 5.1.6.0			

TABLE 78

5.1 EFFECTS OF 2.45 GHz CW MICROWAVE ILLUMINATION ON FORAGING BEHAVIOR OF HONEY BEES

PROTOCOL 5.1.8.0 EFFICIENCY OF COMMUNICATION AND RECRUITMENT

- o HYPOTHESIS OR TASK: MICROWAVE ILLUMINATION WILL AFFECT THE EFFICIENCY OF COMMUNICATION AND RECRUITMENT OF FORAGING HONEY BEES.
- o APPROACH: DETERMINE THE ABILITY FOR FORAGERS TO RECRUIT ADDITIONAL FORAGERS AND THE ABILITY OF RECRUITS TO LOCATE THE FORAGE RESOURCES UNDER CONDITIONS WHEN (A) ONLY THE COLONY IS TREATED, (B) ONLY THE FORAGING AREA IS TREATED, AND (C) BOTH COLONY AND FORAGING AREA ARE TREATED.
- o INFORMATION TO BE DERIVED: TO DETERMINE THE EFFECTS OF MICROWAVE ILLUMINATION ON THE ABILITY OF FORAGERS TO COMMUNICATE WITH EACH OTHER DURING THE RECRUITMENT OF OTHER FORAGERS AND TO DETERMINE IF NEW RECRUITS CAN LOCATE FORAGE RESOURCES IN ILLUMINATED AREAS.
- o EXPERIMENT TIME:

MONTHS TO COMPLETE	12
MAN YEARS	1

- o COST FOR RESEARCH: $23K
- o NEW FACILITIES REQUIRED:

TYPE	COST $	MAY YEARS	TIME TO ACQUIRE
COMMON WITH 5.1.6.0			

TABLE 79

5.1 EFFECTS OF 2.45 GHz CW MICROWAVE ILLUMINATION ON FORAGING BEHAVIOR OF HONEY BEES

PROTOCOL 5.1.9.0 ANALYSIS AND REPORT

- HYPOTHESIS OR TASK: PREPARE A FINAL REPORT ON THE THREE YEAR RESEARCH PROGRAM TO DETERMINE THE EFFECTS OF MICROWAVE ILLUMINATION ON FORAGING BEHAVIOR OF HONEY BEES.
- APPROACH: COMPILE AND ANALYZE DATA DEVELOPED AND REPEAT OR PERFORM NEW EXPERIMENTS WHERE REQUIRED.
- INFORMATION TO BE DERIVED: THE EFFECTS OF 2.45 GHz MICROWAVE ILLUMINATION ON THE FORAGING BEHAVIOR OF HONEY BEES WILL BE EVALUATED.
- EXPERIMENT TIME:

MONTHS TO COMPLETE	6
MAN YEARS	.75

- COST FOR RESEARCH: $18K
- NEW FACILITIES REQUIRED:

TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
NONE			

TABLE 80

5.2 EFFECTS OF 2.45 GH_Z MICROWAVE ILLUMINATION ON INTRA-COLONY BIOLOGY AND BEHAVIOR OF HONEY BEES

PROTOCOL 5.2.1.0 DOSAGE-MORTALITY BIOASSAYS

- o HYPOTHESIS OR TASK: CONDUCT DOSAGE-MORTALITY BIOASSAYS ON HONEY BEE LIFE STAGES TO DETERMINE THE RANGE OF EXPOSURES TO BE USED IN BEHAVIORAL EXPERIMENTS.
- o APPROACH: EGGS, LARVAE, PUPAE AND ADULT BEES WILL BE EXPOSED TO VARIOUS TREATMENTS IN WHICH LEVELS OF ILLUMINATION AND TIME OF EXPOSURE ARE MAJOR VARIABLES. EXPOSURE EFFECTS WILL BE EVALUATED IN TERMS OF SURVIVAL OF TREATED AND SUBSEQUENT STAGES, CHANGES IN DEVELOPMENTAL TIME, TERATOLOGICAL REACTIONS AND REACTIONS OF NURSE BEES TO IMMATURE STAGES.
- o INFORMATION TO BE DERIVED: THE EFFECTS OF MICROWAVES ON THE SURVIVAL, DEVELOPMENTAL TIME AND MORPHOLOGY OF HONEY BEE LIFE STAGES, AS WELL AS THE RANGE OF EXPOSURE LEVELS TO BE USED IN BEHAVIORAL STUDIES WILL BE DETERMINED.
- o EXPERIMENT TIME:

MONTHS TO COMPLETE	6
MAN YEARS	.75

- o COST FOR RESEARCH: $17K
- o NEW FACILITIES REQUIRED:

TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
NONE			

TABLE 81

.LLiS OF 2.45 GHz MICROWAVE ILLUMINATION ON INTRA-COLONY BIOLOGY AND BEHAVIOR OF HONEY BEES

.ROTOCOL 5.2.2.0 BROOD NEST TEMPERATURE REGULATION IN LABORATORY COLONIES

- HYPOTHESIS OR TASK: MICROWAVE ILLUMINATION WILL AFFECT THE THERMOREGULATION BEHAVIOR INVOLVED IN MAINTAINING THE TEMPERATURE (NORMALLY $34^{o} \pm 1^{o}C$) OF THE BROOD NEST.
- APPROACH: LABORATORY COLONIES OF HONEY BEES WILL BE EXPOSED TO VARIOUS LEVELS OF ILLUMINATION UNDER ENVIRONMENTALLY CONTROLLED CONDITIONS AND THE BROOD NEST TEMPERATURE WILL BE DETERMINED BY MEANS OF LIQUID CRYSTAL FIBER-OPTIC PROBES AND/OR BY THERMO SENSING PRILLS INGESTED BY THE BEES.
- INFORMATION TO BE DERIVED: THE ABILITY OF HONEY BEES TO REGULATE THE TEMPERATURE OF THE BROOD NEST DURING MICROWAVE ILLUMINATION WILL BE DETERMINED.
- EXPERIMENT TIME:

MONTHS TO COMPLETE	12
MAN YEARS	.5

- COST FOR RESEARCH: $22K
- NEW FACILITIES REQUIRED:

	TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
5.2.2.1	CHAMBERS (5)	$25K	0.5	6 MONTHS
5.2.2.2	POWER SOURCES (5)	$25K	0.5	6 MONTHS

TABLE 82

172 5.2 EFFECTS OF 2.45 GHz MICROWAVE ILLUMINATION ON INTRA-COLONY BIOLOGY AND BEHAVIOR OF HONEY BEES

PROTOCOL 5.2.3.0 BEHAVIOR OF DRONES IN LABORATORY COLONIES

- HYPOTHESIS OR TASK: MICROWAVE ILLUMINATION WILL AFFECT THE CIRCADIAN RHYTHMS OF DRONES.
- APPROACH: DETERMINE THE POSSIBLE CHANGES IN TIMES AND DURATIONS OF ORIENTATION AND MATING FLIGHTS OF EXPOSED AND UNEXPOSED DRONES UNDER CONTROLLED CONDITIONS.
- INFORMATION TO BE DERIVED: DETERMINATION OF POSSIBLE EFFECTS OF MICROWAVE EXPOSURE ON THE CIRCADIAN RHYTHMS OF DRONES.
- EXPERIMENT TIME:

MONTHS TO COMPLETE	12
MAN YEARS	.5

- COST FOR RESEARCH: $12K
- NEW FACILITIES REQUIRED:

TYPE	COST $	MAN YEARS	TIME TO ACQUIRE

COMMON WITH
5.2.2.0

TABLE 83

5.2 EFFECTS OF 2.45 GHz MICROWAVE ILLUMINATION ON INTRA-COLONY BIOLOGY AND BEHAVIOR OF HONEY BEES

PROTOCOL 5.2.4.0 QUEEN BEHAVIOR IN LABORATORY COLONIES

- o HYPOTHESIS OR TASK: MICROWAVE ILLUMINATION WILL AFFECT OOGENESIS AND THE BEHAVIOR OF QUEEN BEES, ESPECIALLY EGG LAYING BEHAVIOR.
- o APPROACH: ANALYZE EGG LAYING BEHAVIOR OF QUEEN BEES BEFORE, DURING, AND FOLLOWING VARIABLE EXPOSURE TO DETECT ANY ANOMALIES, SUCH AS CHANGES IN THE RATE OF EGG LAYING, DISTRIBUTION IN CELLS, EGG ATTACHMENT POSITION IN CELLS, AND SUBSEQUENT HATCHING AND DEVELOPMENT.
- o INFORMATION TO BE DERIVED: THE EFFECTS OF MICROWAVE ILLUMINATION ON THE OOGENESIS AND EGG LAYING BEHAVIOR OF QUEEN BEES WILL BE DETERMINED.
- o EXPERIMENT TIME:

MONTHS TO COMPLETE	12
MAN YEARS	.5

- o COST FOR RESEARCH: $12K
- o NEW FACILITIES REQUIRED:

TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
COMMON WITH 5.2.2.0			

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TABLE 84

5.2 EFFECTS OF 2.45 GHz MICROWAVE ILLUMINATION ON INTRA-COLONY BIOLOGY AND BEHAVIOR OF HONEY BEES

<u>PROTOCOL 5.2.5.0 DANCE BEHAVIOR</u>

- o <u>HYPOTHESIS OR TASK</u>: MICROWAVE ILLUMINATION WILL AFFECT THE DANCES USED BY BEES TO COMMUNICATE WITH EACH OTHER.
- o <u>APPROACH</u>: THE EFFECTS OF MICROWAVE EXPOSURE ON COMMUNICATION DANCES WILL BE DETERMINED BY ANALYZING THE MAJOR VARIABLES AND RECRUITMENT EFFICIENCY OF DANCES BY BEES FORAGING AT KNOWN LOCATIONS.
- o <u>INFORMATION TO BE DERIVED</u>: THIS STUDY WILL DETERMINE IF MICROWAVE ILLUMINATION WILL AFFECT THE ABILITY OF BEES TO COMMUNICATE INFORMATION RELATING TO FORAGING ACTIVITIES.
- o <u>EXPERIMENT TIME</u>:

MONTHS TO COMPLETE	12
MAN YEARS	.5

- o <u>COST FOR RESEARCH</u>: $12K
- o <u>NEW FACILITIES REQUIRED</u>:

<u>TYPE</u>	<u>COST $</u>	<u>MAN YEARS</u>	<u>TIME TO ACQUIRE</u>
COMMON WITH 5.2.2.0			

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5.2 EFFECTS OF 2.45 GHz MICROWAVE ILLUMINATION ON INTRA-COLONY BIOLOGY AND BEHAVIOR OF HONEY BEES

PROTOCOL 5.2.6.0 DEFENSIVENESS (AGGRESSIVENESS)

- HYPOTHESIS OR TASK: MICROWAVE ILLUMINATION WILL DISTURB COLONIES AND THEREBY INCREASE THE TENDENCY TO STING NEAR THE HIVE.
- APPROACH: DIFFERENCES IN LEVELS OF DEFENSIVE BEHAVIOR BETWEEN EXPOSED AND UNEXPOSED COLONIES WILL BE DETERMINED BY QUANTITATIVE METHODS.
- INFORMATION TO BE DERIVED: THIS STUDY WILL DTERMINE IF MICROWAVE ILLUMINATION WILL INCREASE THE DEFENSIVENESS OF COLONIES.
- EXPERIMENT TIME:

MONTHS TO COMPLETE	12
MAN YEARS	.25

- COST FOR RESEARCH: $6.25K
- NEW FACILITIES REQUIRED:

	TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
5.2.6.1	FIELD EXPOSURE AREA	$70K	1	1 YEAR

TABLE 86

5.2 EFFECTS OF 2 45 GHz MICROWAVE ILLUMINATION ON INTRA-COLONY BIOLOGY AND BEHAVIOR OF HONEY BEES

PROTOCOL 5.2.7.0 BROOD NEST TEMPERATURE REGULATION OF FIELD COLONIES

- o HYPOTHESIS OR TASK: MICROWAVE ILLUMINATION WILL AFFECT THERMOREGULATION BEHAVIOR INVOLVED IN MAINTAINING NORMAL BROOD NEST TEMPERATURE.
- o APPROACH: BROOD NEST TEMPERATURE OF FIELD COLONIES WILL BE DETERMINED BY MEANS OF LIQUID CRYSTAL FIBER-OPTIC PROBES AND/OR THERMO SENSING PRILLS INGESTED BY THE BEES.
- o INFORMATION TO BE DERIVED: DETERMINATION OF THE ABILITY OF EXPOSED COLONIES TO REGULATE BROOD NEST TEMPERATURES UNDER FIELD CONDITIONS.
- o EXPERIMENT TIME:

MONTHS TO COMPLETE	12
MAN YEARS	.25

- o COST FOR RESEARCH: $6.25K
- o NEW FACILITIES REQUIRED:

TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
COMMON WITH 5.2.6.0			

5.2 EFFECTS OF 2.45 GHz MICROWAVE ILLUMINATION ON INTRA-COLONY BIOLOGY AND BEHAVIOR OF HONEY BEES

PROTOCOL 5.2.8.0 BEHAVIOR OF DRONES IN FIELD COLONIES

- HYPOTHESIS OR TASK: MICROWAVE ILLUMINATION WILL AFFECT THE CIRCADIAN RHYTHMS OF DRONES.
- APPROACH: CHANGES IN DRONE BEHAVIOR UNDER FIELD CONDITIONS WILL BE DETERMINED BY STUDYING THE TIMES AND DURATIONS OF ORIENTATION AND MATING FLIGHTS OF DRONES FROM EXPOSED AND UNEXPOSED COLONIES.
- INFORMATION TO BE DERIVED: DETERMINATION OF POSSIBLE MICROWAVE EXPOSURE EFFECTS ON CIRCADIAN RHYTHMS OF DRONES.
- EXPERIMENT TIME:

MONTHS TO COMPLETE	12
MAN YEARS	.25

- COST FOR RESEARCH: $6.25K
- NEW FACILITIES REQUIRED:

TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
COMMON WITH 5.2.6.0			

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TABLE 88

5.2 EFFECTS OF 2.45 GHz MICROWAVE ILLUMINATION ON INTRA-COLONY BIOLOGY AND BEHAVIOR OF HONEY BEES

PROTOCOL 5.2.9.0 NEST CLEANING BEHAVIOR

- HYPOTHESIS OR TASK: MICROWAVE ILLUMINATION WILL AFFECT THE NEST CLEANING ABILITY OF BEES.
- APPROACH: DETERMINE IF THERE ARE DIFFERENCES IN THE REMOVAL OF DEAD BEES AND FOREIGN DEBRIS FROM TREATED AND UNTREATED COLONIES.
- INFORMATION TO BE DERIVED: DETERMINATION OF POSSIBLE MICROWAVE EFFECTS ON NEST CLEANING BEHAVIOR.
- EXPERIMENT TIME:

MONTHS TO COMPLETE	12
MAN YEARS	.25

- COST FOR RESEARCH: $6.25K
- NEW FACILITIES REQUIRED:

TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
COMMON WITH 5.2.6.0			

TABLE 89

5.2 EFFECTS OF 2.45 GHz MICROWAVE ILLUMINATION ON INTRA-COLONY BIOLOGY AND BEHAVIOR OF HONEY BEES

PROTOCOL 5.2.10.0 CONSTRUCTION OF HONEY COMB

- HYPOTHESIS OR TASK: MICROWAVE ILLUMINATION WILL AFFECT THE CONSTRUCTION OF HONEY COMB.
- APPROACH: DETERMINE THE ABILITY OF BEES TO SECRETE WAX AND CONSTRUCT HONEY COMBS OF NORMAL SHAPE AND ORIENTATION.
- INFORMATION TO BE DERIVED: THIS STUDY WILL DETERMINE IF ANY ASPECT OF HONEY COMB CONSTRUCTION IS AFFECTED, INCLUDING GRAVITY PERCEPTION AND ORIENTATION.
- EXPERIMENT TIME:

MONTHS TO COMPLETE	12
MAN YEARS	.25

- COST FOR RESEARCH: $6.25K
- NEW FACILITIES REQUIRED:

TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
COMMON WITH 5.2.6.0			

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TABLE 90

5.2 EFFECTS OF 2.45 GHz MICROWAVE ILLUMINATION ON INTRA-COLONY BIOLOGY AND BEHAVIOR OF HONEY BEES

PROTOCOL 5.2.11.0 NECTAR PROCESSING

- HYPOTHESIS OR TASK: MICROWAVE ILLUMINATION WILL AFFECT THE ABILITY OF BEES TO PROCESS NECTAR TO HONEY.
- APPROACH: MONITOR THE WATER CONTENT AND SUGAR COMPOSITION OF NECTAR AND HONEY IN TREATED AND CONTROL COLONIES.
- INFORMATION TO BE DERIVED: DETERMINATION OF POSSIBLE MICROWAVE AFFECTS ON THE ABILITY OF BEES TO PROCESS NECTAR TO HONEY.
- EXPERIMENT TIME:
  - MONTHS TO COMPLETE: 12
  - MAN YEARS: .25
- COST FOR RESEARCH: $6.25K
- NEW FACILITIES REQUIRED:

TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
COMMON WITH 5.2.6.0			

5.2 EFFECTS OF 2.45 GHz MICROWAVE ILLUMINATION ON INTRA-COLONY BIOLOGY AND BEHAVIOR OF HONEY BEES

PROTOCOL 5.2.12.0 REPRODUCTION IN FIELD COLONIES

- HYPOTHESIS OR TASK: MICROWAVE ILLUMINATION WILL AFFECT THE REPRODUCTIVE CAPACITY OF COLONIES.
- APPROACH: THE RATE OF EGG LAYING AND BROOD SURVIVAL WILL BE DETERMINED AS A MEASURE OF REPRODUCTIVE CAPACITY.
- INFORMATION TO BE DERIVED: THE EFFECTS OF MICROWAVE ILLUMINATION ON THE REPRODUCTIVE CAPACITY OF COLONIES UNDER FIELD CONDITIONS WILL BE DETERMINED.
- EXPERIMENT TIME:

MONTHS TO COMPLETE	12
MAN YEARS	.25

- COST FOR RESEARCH: $6.25K
- NEW FACILITIES REQUIRED:

TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
COMMON WITH 5.2.6.0			

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TABLE 92

5.2 EFFECTS OF 2.45 GHz MICROWAVE ILLUMINATION ON INTRA-COLONY BIOLOGY AND BEHAVIOR OF HONEY BEES

PROTOCOL 5.2.13.0 SUSCEPTIBILITY TO DISEASE AND PARASITISM

- o HYPOTHESIS OR TASK: MICROWAVE ILLUMINATION WILL INCREASE THE SUSCEPTIBILITY OF HONEY BEES TO DISEASE AND PARASITISM.
- o APPROACH: EXAMINE EXPOSED AND UNEXPOSED COLONIES TO DETERMINE IF THERE ARE CHANGES IN THE LEVELS OF INCIDENCE OF DISEASES AND PARASITES AND THE ABILITY TO RESIST INTRODUCED ORGANISMS.
- o INFORMATION TO BE DERIVED: THIS STUDY WILL DETERMINE IF EXPOSURE TO MICROWAVES AFFECTS RESISTANCE OF HONEY BEES TO DISEASES AND PARASITES.
- o EXPERIMENT TIME:

MONTHS TO COMPLETE	12
MAN YEARS	.25

- o COST FOR RESEARCH: $6.25K
- o NEW FACILITIES REQUIRED:

TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
COMMON WITH 5.2.6.0			

5.2 EFFECTS OF 2.45 GHz MICROWAVE ILLUMINATION ON INTRA-COLONY BIOLOGY AND BEHAVIOR OF HONEY BEES

PROTOCOL 5.2.14.0 ANALYSIS AND REPORT

- HYPOTHESIS OR TASK: PREPARE A FINAL REPORT ON THE THREE YEAR RESEARCH PROGRAM TO DETERMINE THE EFFECTS OF MICROWAVE ILLUMINATION ON INTRA-COLONY BIOLOGY AND BEHAVIOR OF HONEY BEES.
- APPROACH: COMPILE AND ANALYZE DATA AND REPEAT OR PERFORM NEW EXPERIMENTS WHERE REQUIRED.
- INFORMATION TO BE DERIVED: THE EFFECTS OF 2.45 GHz MICROWAVE ILLUMINATION ON THE INTRA-COLONY BIOLOGY AND BEHAVIOR OF HONEY BEES WILL BE DETERMINED.
- EXPERIMENT TIME:

MONTHS TO COMPLETE	6
MAN YEARS	.75

- COST FOR RESEARCH: $18K
- NEW FACILITIES REQUIRED:

TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
NONE			

TABLE 94

5.3 EFFECTS OF CW 2.45 GHz MICROWAVE ILLUMINATION ON REPRESENTATIVE ARTHROPODS (COLEOPTERA, DIPTERA, LEPIDOPTERA, HEMIPTERA, THYSANOPTERA, ISOPTERA, ORTHOPTERA, ODONATA, ARACHNIDA, CHILOPODA, AND DIPLOPODA)

PROTOCOL 5.3.1.0 DOSAGE-MORTALITY BIOASSAYS

- HYPOTHESIS OR TASK: A RANGE OF SUSCEPTIBILITY MAY EXIST IN ARTHROPODS OF DIFFERENT CLASSES AND ORDERS, MAKING IT NECESSARY TO CONDUCT DOSAGE-MORTALITY BIOASSAYS ON LIFE STAGES OF REPRESENTATIVE ARTHROPODS TO DETERMINE THE RANGE OF EXPOSURES TO BE USED IN BEHAVIORAL STUDIES.
- APPROACH: ARTHROPODS REPRESENTING DIVERSE CLASSES AND ORDERS WILL BE EXPOSED TO VARIOUS TREATMENTS IN WHICH LEVELS OF ILLUMINATION AND TIME OF EXPOSURE ARE MAJOR VARIABLES. EXPOSURE EFFECTS WILL BE EVALUATED IN TERMS OF SURVIVAL OF TREATED AND SUBSEQUENT STAGES, CHANGES IN DEVELOPMENT TIME AND TERATOLOGICAL REACTIONS.
- INFORMATION TO BE DERIVED: THE EFFECTS OF MICROWAVE ILLUMINATION ON THE SURVIVAL, DEVELOPMENTAL TIME, AND MORPHOLOGY OF LIFE STAGES AND THE RANGE OF EXPOSURES TO BE USED IN BEHAVIORAL STUDIES WILL BE DETERMINED.
- EXPERIMENT TIME:

MONTHS TO COMPLET	6
MAN YEARS	1.5

- COST FOR RESEARCH: $45K
- NEW FACILITIES REQUIRED:

	TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
5.3.2.1	CHAMBERS (5)	$40K	0.6	6 MONTHS
5.3.2.2	POWER SOURCES (5)	$25K	0.6	6 MONTHS

5.3 EFFECTS OF CW 2.45 GHz MICROWAVE ILLUMINATION ON REPRESENTATIVE ARTHROPODS (COLEOPTERA, DIPTERA, LEPIDOPTERA, HEMIPTERA, THYSANOPTERA, ISOPTERA, ORTHOPTERA, ODONATA, ARACHNIDA, CHILOPODA, AND DIPLOPODA)

PROTOCOL 5.3.2.0 AVOIDANCE-ATTRACTION

- HYPOTHESIS OR TASK: ARTHROPODS CAN SENSE MICROWAVE ENERGY SIMILARLY TO OTHER EXOGENOUS STIMULI AND WILL RESPOND BY ATTRACTION TO OR AVOIDANCE OF TREATED AREAS, RELATIVE TO ACCESSIBLE UNTREATED AREAS.
- APPROACH: DETERMINE THE RESPONSE THRESHOLD FOR AVOIDANCE OR ATTRACTION OF REPRESENTATIVE ARTHROPODS. DETERMINE IF ADAPTATION AND/OR HABITUATION OCCURS. IF SO, ARTHROPODS WILL BE EXPOSED TO MICROWAVES AFTER VARIOUS LENGTHS OF RECOVERY TIME TO TEST FOR RESTORATION OF SENSITIVITY.
- INFORMATION TO BE DERIVED: THIS STUDY WILL DETERMINE (A) IF ARTHROPODS CAN SENSE MICROWAVE FIELDS, (B) IF SENSORY ADAPTATION TO THE FIELD OCCURS, (C) IF ARTHROPODS CAN RESPOND ADAPTIVELY, AND (D) IF RESTORATION OF SENSITIVITY OCCURS RAPIDLY.
- EXPERIMENT TIME:

MONTHS TO COMPLETE	18
MAN YEARS	0.75

- COST FOR RESEARCH: $18K
- NEW FACILITIES REQUIRED:

TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
COMMON WITH 5.3.1.0			

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TABLE 96

5.3 EFFECTS OF CW 2.45 GHz MICROWAVE ILLUMINATION ON REPRESENTATIVE ARTHROPODS (COLEOPTERA, DIPTERA, LEPIDOPTERA, HEMIPTERA, THYSANOPTERA, ISOPTERA, ORTHOPTERA, ODONATA, ARACHNIDA, CHILOPODA, AND DIPLOPODA)

PROTOCOL 5.3.3.0 REPRODUCTIVE BEHAVIOR

- HYPOTHESIS OR TASK: MICROWAVE ILLUMINATION WILL AFFECT THE REPRODUCTIVE BEHAVIOR OF REPRESENTATIVE ARTHROPODS.
- APPROACH: THE EFFECTS OF MICROWAVE ILLUMINATION ON REPRODUCTIVE BEHAVIOR WILL BE EVALUATED IN TERMS OF ABILITY TO LOCATE A MATE, COURTSHIP AND MATING, OVIPOSITION, BROOD CARE AND LEVEL OF REPRODUCTION.
- INFORMATION TO BE DERIVED: DETERMINATION OF THE EFFECTS OF MICROWAVE ILLUMINATION ON THE REPRODUCTIVE BEHAVIOR OF ARTHROPODS.
- EXPERIMENT TIME:

MONTHS TO COMPLETE	18
MAN YEARS	0.75

- COST FOR RESEARCH: $12K
- NEW FACILITIES REQUIRED:

TYPE	COST $	MAN YEARS	TIME TO ACQUIRE

COMMON WITH 5.3.1.0

TABLE 97

5.3 EFFECTS OF CW 2.45 GHz MICROWAVE ILLUMINATION ON REPRESENTATIVE ARTHROPODS (COLEOPTERA, DIPTERA, LEPIDOPTERA, HEMIPTERA, THYSANOPTERA, ISOPTERA, ORTHOPTERA, ODONATA, ARACHNIDA, CHILOPODA, AND DIPLOPODA)

PROTOCOL 5.3.4.0 PERIODICITY OF BEHAVIOR

- HYPOTHESIS OR TASK: MICROWAVE ILLUMINATION WILL AFFECT THE PERIODICITY OF BEHAVIOR OF ARTHROPODS.
- APPROACH: THE EFFECTS OF MICROWAVE ILLUMINATION ON REPRESENTATIVE ACTIVITIES OF ARTHROPODS THAT SHOW A RECURRENCE AT REGULAR INTERVALS WILL BE DETERMINED.
- INFORMATION TO BE DERIVED: DETERMINATION OF POSSIBLE MICROWAVE EFFECTS ON CIRCADIAN RHYTHMS OF ARTHROPODS.
- EXPERIMENT TIME:
  - MONTHS TO COMPLETE: 18
  - MAN YEARS: 0.75
- COST FOR RESEARCH: $18K
- NEW FACILITIES REQUIRED:

TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
COMMON WITH 5.3.1.0			

TABLE 98

5.3 EFFECTS OF CW 2.45 GHz MICROWAVE ILLUMINATION ON REPRESENTATIVE ARTHROPODS (COLEOPTERA, DIPTERA, LEPIDOPTERA, HEMIPTERA, THYSANOPTERA, ISOPTERA, ORTHOPTERA, ODONATA, ARACHNIDA, CHILOPODA, AND DIPLOPODA)

PROTOCOL 5.3.5.0 FEEDING BEHAVIOR

- o HYPOTHESIS OR TASK: MICROWAVE ILLUMINATION WILL AFFECT THE FEEDING BEHAVIOR OF ARTHROPODS.
- o APPROACH: THE EFFECTS OF MICROWAVE EXPOSURE ON THE LOCATION AND CONSUMPTION OF FOOD SOURCES BY REPRESENTATIVE ARTHROPODS WILL BE DETERMINED.
- o INFORMATION TO BE DERIVED: THE EFFECTS OF MICROWAVE EXPOSURE ON THE FEEDING BEHAVIOR OF ARTHROPODS WILL BE DETERMINED.
- o EXPERIMENT TIME:

MONTHS TO COMPLETE	18
MAN YEARS	0.75

- o COST FOR RESEARCH: $18K
- o NEW FACILITIES REQUIRED:

TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
COMMON WITH 5.3.1.0			

TABLE 99

5.3 EFFECTS OF CW 2.45 GHz MICROWAVE ILLUMINATION ON REPRESENTATIVE ARTHROPODS (COLEOPTERA, DIPTERA, LEPIDOPTERA, HEMIPTERA, THYSANOPTERA, ISOPTERA, ORTHOPTERA, ODONATA, ARACHNIDA, CHILOPODA, AND DIPLOPODA)

PROTOCOL 5.3.6.0 ESCAPE AND DEFENSE REACTIONS

- HYPOTHESIS OR TASK: MICROWAVE ILLUMINATION WILL AFFECT THE ABILITY OF ARTHROPODS TO DEFEND THEMSELVES AND TO ESCAPE FROM NOXIOUS STIMULI OF NATURAL ENEMIES.
- APPROACH: DETERMINE THE EFFECTS OF MICROWAVE ILLUMINATION ON THE CHARACTERISTIC ESCAPE AND DEFENSE REACTIONS OF REPRESENTATIVE ARTHROPODS.
- INFORMATION TO BE DERIVED: DETERMINATION OF POSSIBLE MICROWAVE EFFECTS ON ESCAPE AND DEFENSE REACTIONS OF ARTHROPODS.
- EXPERIMENT TIME:

MONTHS TO COMPLETE	18
MAN YEARS	0.75

- COST FOR RESEARCH: $18K
- NEW FACILITIES REQUIRED:

TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
COMMON WITH 5.3.1.0			

TABLE 100

5.3 EFFECTS OF CW 2.45 GHz MICROWAVE ILLUMINATION ON REPRESENTATIVE ARTHROPODS (COLEOPTERA, DIPTERA, LEPIDOPTERA, HEMIPTERA, THYSANOPTERA, ISOPTERA, ORTHOPTERA, O DONATA, ARACHNIDA, CHILOPODA, AND DIPLOPODA)

PROTOCOL 5.3.7.0 SUSCEPTIBILITY TO DISEASE AND PARASITISM

- HYPOTHESIS OR TASK: MICROWAVE ILLUMINATION WILL INCREASE THE SUSCEPTIBILITY OF ARTHROPODS TO DISEASE AND PARASITISM.
- APPROACH: THE ABILITY OF REPRESENTATIVE ARTHROPODS TO RESIST DISEASES AND PARASITES WILL BE STUDIED.
- INFORMATION TO BE DERIVED: THE EFFECTS OF MICROWAVE ILLUMINATION ON THE SUSCEPTIBILITY OF ARTHROPODS TO DISEASES AND PARASITES WILL BE DETERMINED.
- EXPERIMENT TIME:

MONTHS TO COMPLETE	18
MAN YEARS	0.75

- COST FOR RESEARCH: $18K
- NEW FACILITIES REQUIRED:

TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
COMMON WITH 5.3.1.0			

TABLE 101

5.3 EFFECTS OF CW 2.45 GHz MICROWAVE ILLUMINATION ON REPRESENTATIVE ARTHROPODS (COLEOPTERA, DIPTERA, LEPIDOPTERA, HEMIPTERA, THYSANOPTERA, ISOPTERA, ORTHOPTERA, ODONATA, ARACHNIDA, CHILOPODA, AND DIPLOPODA)

PROTOCOL 5.3.8.0 ANALYSIS AND REPORT

- HYPOTHESIS OR TASK: PREPARE A FINAL REPORT ON THE THREE YEAR RESEARCH PROGRAM TO DETERMINE THE EFFECTS OF MICROWAVE ILLUMINATION ON THE BEHAVIOR OF REPRESENTATIVE ARTHROPODS.
- APPROACH: COMPILE AND ANALYZE DATA DEVELOPED AND REPEAT OR PERFORM NEW EXPERIMENTS WHERE REQUIRED.
- INFORMATION TO BE DERIVED: THE EFFECTS OF CW 2.45 GHz MICROWAVE ILLUMINATION ON THE BIOLOGY AND BEHAVIOR OF REPRESENTATIVE ARTHROPODS WILL BE EVALUATED.
- EXPERIMENT TIME:

MONTHS TO COMPLETE	6
MAN YEARS	0.75

- COST FOR RESEARCH: $18K
- NEW FACILITIES REQUIRED:

TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
NONE			

TABLE 102

5.4 EFFECTS OF CW 2.45 GHz MICROWAVE ILLUMINATION ON BEHAVIOR OF NEMATODES (ROUNDWORMS), ANNELIDS (EARTHWORMS) AND GASTROPODS (SNAILS AND SLUGS)

PROTOCOL 5.4.1.0 SURVIVAL AND LONGEVITY

- <u>HYPOTHESIS OR TASK</u>: CONDUCT DOSAGE-MORTALITY BIOASSAYS ON REPRESENTATIVE NEMATODES, ANNELIDS AND GASTROPODS TO DETERMINE THE RANGE OF EXPOSURES TO BE USED IN BEHAVIORAL EXPERIMENTS.
- <u>APPROACH</u>: REPRESENTATIVE SPECIES WILL BE EXPOSED TO VARIOUS TREATMENTS IN WHICH LEVELS OF ILLUMINATION AND TIME OF EXPOSURE ARE MAJOR VARIABLES. EXPOSURE EFFECTS WILL BE EVALUATED IN TERMS OF SURVIVAL OF TREATED AND SUBSEQUENT STAGES, CHANGES IN DEVELOPMENT TIME, AND TERATOLOGICAL REACTIONS.
- <u>INFORMATION TO BE DERIVED</u>: THE EFFECTS OF MICROWAVE ILLUMINATION ON THE SURVIVAL, DEVELOPMENTAL TIME, AND MORPHOLOGY OF LIFE STAGES AND THE RANGE OF EXPOSURES TO BE USED IN BEHAVIORAL STUDIES WILL BE DETERMINED.
- <u>EXPERIMENT TIME</u>:
  - MONTHS TO COMPLETE: 6
  - MAN YEARS: 1.5
- <u>COST FOR RESEARCH</u>: $40K
- <u>NEW FACILITIES REQUIRED</u>:

	TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
5.4.1.1	CHAMBERS (5)	$50K	0.6	6 MONTHS
5.4.1.2	POWER SOURCES (5)	$25K	0.6	6 MONTHS

TABLE 103

5.4 EFFECTS OF CW 2.45 GHz MICROWAVE ILLUMINATION ON BEHAVIOR OF NEMATODES (ROUNDWORMS), ANNELIDS (EARTHWORMS) AND GASTROPODS (SNAILS AND SLUGS)

PROTOCOL 5.4.2.0 AVOIDANCE-ATTRACTION

- HYPOTHESIS OR TASK: NEMATODES, ANNELIDS, AND GASTROPODS CAN SENSE MICROWAVE ENERGY SIMILARLY TO OTHER EXOGENOUS STIMULI AND WILL RESPOND BY ATTRACTION OR AVOIDANCE OF TREATED AREAS, RELATIVE TO ACCESSIBLE UNTREATED AREAS.
- APPROACH: DETERMINE THE RESPONSE THRESHOLD FOR AVOIDANCE OR ATTRACTION OF REPRESENTATIVE SPECIES. DETERMINE IF ADAPTATION AND/OR HABITUATION OCCURS. IF SO, SPECIMENS WILL BE EXPOSED TO MICROWAVES AFTER VARIOUS LENGTHS OF RECOVERY TIME TO TEST FOR RESTORATION OF SENSITIVITY.
- INFORMATION TO BE DERIVED: THIS STUDY WILL DETERMINE (A) IF NEMATODES, ANNELIDS AND GASTROPODS CAN SENSE MICROWAVE FIELDS, (B) IF SENSORY ADAPTATION TO THE FIELD OCCURS, (C) IF REPRESENTATIVE SPECIES CAN RESPOND ADAPTIVELY, AND (D) IF RESTORATION OF SENSITIVITY OCCURS RAPIDLY.
- EXPERIMENT TIME:

MONTHS TO COMPLETE	18
MAN YEARS	1.5

- COST FOR RESEARCH: $33K
- NEW FACILITIES REQUIRED:

TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
COMMON WITH 5.4.1.0			

TABLE 104

5.4 EFFECTS OF CW 2.45 GHz MICROWAVE ILLUMINATION ON BEHAVIOR OF NEMATODES (ROUNDWORMS), ANNELIDS (EARTHWORMS) AND GASTROPODS (SNAILS AND SLUGS)

<u>PROTOCOL 5.4.3.0 REPRODUCTIVE BEHAVIOR</u>

- o <u>HYPOTHESIS OR TASK</u>: MICROWAVE ILLUMINATION WILL AFFECT THE REPRODUCTIVE BEHAVIOR OF REPRESENTATIVE NEMATODES, ANNELIDS AND GASTROPODS.
- o <u>APPROACH</u>: THE EFFECTS OF MICROWAVE ILLUMINATION ON REPRODUCTIVE BEHAVIOR WILL BE EVALUATED IN TERMS OF MATE LOCATION, MATING AND LEVEL OF REPRODUCTION.
- o <u>INFORMATION TO BE DERIVED</u>: DETERMINATION OF THE EFFECTS OF MICROWAVE ILLUMINATION ON THE REPRODUCTIVE BEHAVIOR OF NEMATODES, ANNELIDS, AND GASTROPODS.
- o <u>EXPERIMENT TIME</u>:

MONTHS TO COMPLETE	18
MAN YEARS	1.5

- o <u>COST FOR RESEARCH</u>: $33K
- o <u>NEW FACILITIES REQUIRED</u>:

TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
COMMON WITH 5.4.1.0			

194

TABLE 105

5.4 EFFECTS OF CW 2.45 GHz MICROWAVE ILLUMINATION ON BEHAVIOR OF NEMATODES (ROUNDWORMS), ANNELIDS (EARTHWORMS) AND GASTROPODS (SNAILS AND SLUGS)

PROTOCOL 5.4.4.0 FEEDING BEHAVIOR

- o HYPOTHESIS OR TASK: MICROWAVE ILLUMINATION WILL AFFECT THE FEEDING BEHAVIOR OF NEMATODES, ANNELIDS AND GASTROPODS.
- o APPROACH: THE EFFECTS OF MICROWAVE EXPOSURE ON THE LOCATION AND CONSUMPTION OF FOOD SOURCES BY REPRESENTATIVE SPECIES WILL BE DETERMINED.
- o INFORMATION TO BE DERIVED: THE EFFECTS OF MICROWAVE EXPOSURE ON THE FEEDING BEHAVIOR OF NEMATODES, ANNELIDS, AND GASTROPODS WILL BE DETERMINED.
- o EXPERIMENT TIME:

MONTHS TO COMPLETE	18
MAN YEARS	1.5

- o COST FOR RESEARCH: $33K
- o NEW FACILITIES REQUIRED:

TYPE	COST $	MAN YEARS	TIME TO ACQUIRE

COMMON WITH 5.4.1.0

TABLE 106

5.4 EFFECTS OF CW 2.45 GHz MICROWAVE ILLUMINATION ON BEHAVIOR OF NEMATODES (ROUNDWORMS), ANNELIDS (EARTHWORMS) AND GASTROPODS (SNAILS AND SLUGS)

PROTOCOL 5.4.5.0 MOVEMENT

- o HYPOTHESIS OR TASK: MICROWAVE ILLUMINATION WILL AFFECT THE MOVEMENTS OF NEMATODES, ANNELIDS AND GASTROPODS.
- o APPROACH: THE EFFECTS OF MICROWAVE EXPOSURE ON THE DISTRIBUTION, DISPERSAL, ORIENTATION AND ABUNDANCE OF REPRESENTATIVE SPECIES WILL BE DETERMINED.
- o INFORMATION TO BE DERIVED: THE EFFECTS OF MICROWAVE EXPOSURE ON THE MOVEMENT OF NEMATODES, ANNELIDS AND GASTROPODS WILL BE DETERMINED.
- o EXPERIMENT TIME:

MONTHS TO COMPLETE	18
MAN YEARS	1.5

- o COST FOR RESEARCH: $33K
- o NEW FACILITIES REQUIRED:

TYPE	COST $	MAN YEARS	TIME TO ACQUIRE

COMMON WITH 5.4.1.0

TABLE 107

5.4 EFFECTS OF CW 2.45 GHz MICROWAVE ILLUMINATION ON BEHAVIOR OF NEMATODES (ROUNDWORMS), ANNELIDS (EARTHWORMS) AND GASTROPODS (SNAILS AND SLUGS)

PROTOCOL 5.4.6.0 ANALYSIS AND REPORT

- HYPOTHESIS OR TASK: PREPARE A FINAL REPORT ON THE THREE YEAR RESEARCH PROGRAM TO DETERMINE THE EFFECTS OF MICROWAVE ILLUMINATION ON THE BEHAVIOR OF NEMATODES, ANNELIDS AND GASTROPODS.
- APPROACH: COMPILE AND ANALYZE DATA DEVELOPED AND REPEAT OR PERFORM NEW EXPERIMENTS WHERE REQUIRED.
- INFORMATION TO BE DERIVED: THE EFFECTS OF 2.45 GHz MICROWAVE ILLUMINATION ON THE BIOLOGY AND BEHAVIOR OF REPRESENTATIVE NEMATODES, ANNELIDS AND GASTROPODS WILL BE EVALUATED.
- EXPERIMENT TIME:

MONTHS TO COMPLETE	6
MAN YEARS	0.75

- COST FOR RESEARCH: $18K
- NEW FACILITIES REQUIRED:

TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
NONE			

MILESTONE AND FUNDING SUMMARY

TABLE 108

MILESTONE AND FUNDING SUMMARY

	PHASE A YEAR (0 1 2 3)	COST $K Exper.	COST $K Facil.	Question
5.1.0.0 Foraging Behavior of Honey Bees	∇	--	---	263
5.1.1.0 Survival and Longevity	∇	11	---	
5.1.2.0 Orientation and Flight Behavior	∇	11	4.5	
5.1.3.0 Foraging Simulation	∇	22	4.5	
5.1.4.0 Avoidance - Attraction	∇	22	4.5	
5.1.5.0 Foraging Arena	∇	22	4.5	
5.1.6.0 Attraction to Foraging Area	∇	23	70.	
5.1.7.0 Foraging Efficiency	∇	23	---	
5.1.8.0 Efficiency of Communication and Recruitment	∇	23	---	
5.1.9.0 Analysis and Report	∇	18	---	
5.2.0.0 Intra-Colony Biology and Behavior	∇	--	---	263
5.2.1.0 Dosage-Mortality Bioassays	∇	17	---	
5.2.2.0 Brood Nest Temperature	∇	22	50.	

TABLE 108. - Continued

	PHASE A YEAR 0 1 2 3	COST $K Exper.	Facil.	Question
5.2.3.0 Drone Behavior	∇	12	---	
5.2.4.0 Queen Behavior	∇	12	---	
5.2.5.0 Dance Behavior	∇	12	---	
5.2.6.0 Defensiveness (Agressiveness)	∇	6.25	70	
5.2.7.0 Brood Nest Temperature	∇	6.25	---	
5.2.8.0 Drone Behavior	∇	6.25	---	
5.2.9.0 Nest Cleaning	∇	6.25	---	
5.2.10.0 Honey Comb Construction	∇	6.25	---	
5.2.11.0 Nectar Processing	∇	6.25	---	
5.2.12.0 Reproduction	∇	6.25	---	
5.2.13.0 Disease and Parasitism	∇	6.25	---	
5.2.14.0 Analysis and Report	∇	18	---	
5.3.0.0 Other Representative Arthropods	∇	---	---	236
5.3.1.0 Dosage-Mortality	∇	45	65	
5.3.2.0 Avoidance-Attraction	∇	18	--	

TABLE 108. - Concluded

	PHASE A YEAR 0 1 2 3	COST $K Exper.	Facil.	Question
5.3.3.0 Reproductive Behavior	∇	[illegible]	---	
5.3.4.0 Periodicity of Behavior	∇	[illegible]	---	
5.3.5.0 Feeding Behavior	∇	18	---	
5.3.6.0 Escape and Defense	∇	18	---	
5.3.7.0 Disease and Parasitism	∇	18	---	
5.3.8.0 Analysis and Report	∇	18	---	
5.4.0.0 Nematodes, Annelids and Gastropods	∇	--	---	265
5.4.1.0 Survival and Longevity	∇	40	75	
5.4.2.0 Avoidance-Attraction	∇	33	---	
5.4.3.0 Reproductive Behavior	∇	33	---	
5.4.4.0 Feeding Behavior	∇	33	---	
5.4.5.0 Movement	∇	33	---	
5.4.6.0 Analysis and Report	∇	18	---	

PILOT EXPERIMENTATION

During this study, considerable familiarity has been obtained with various power sources and chambers commonly used for microwave research on vertebrates.

Chambers of a considerably different design are necessary for much of the research that needs to be done on insects. For example, chambers must 1) allow observation of the activities of subjects during exposure, 2) permit subjects to move in and out of the chamber at will, and 3) allow subjects to choose between various levels of exposure.

A chamber and power source suitable for preliminary dosage mortality and behavioral studies as been constructed. Preliminary survival and behavioral experiments are currently in progress.

Insufficient data are available to generate meaningful results. The experimental apparatus seems to be performing satisfactorily and the bioassay procedures are being validated.

PRIORITIZED LIST OF QUESTIONS

1. WHAT IS THE DOSE AND DOSE RATE NECESSARY TO ELICIT CHANGE IN SPECIES NUMBER AND DIVERSITY OF SOIL AND FOLIAR FUNGI?

a. Dose and Dose Rate Experiments. - The microwave dosages and dose rates to obtain 10, 50, and 90 percent reductions in number and diversity of soil-fungal species per unit area should be determined for as many taxonomic groups as is feasible. The first task is to determine the minimum dose required to achieve visible changes in species number and diversity. Secondly, determine change as a function of dose rate. We know change is a function of dose; however, it is vital to know if change also is a function of dose rate to predict species changes as as function of distance from receiving antennae. Power densities under antennae may approach 25 mW/cm^2 and decrease with distance to 0.01 mW/cm^2. According to Vela, et al. (54), there is a significant reduction in soil fungi after exposure to 40,000 joules of 2.457 GHz microwaves. At a dose rate of 25 mW/cm^2 it would take only 18 days to accumulate 40,000 joules of energy (if all the energy were absorbed), but 127 years at a dose arate of 0.01 mW/cm^2. The critical question is to determine if fungitoxic effects observed with 40,000 joules and other dosages applied at a rate of 1 kW/cm^2 (55,54), are the same as 40,000 joules applied at 25 mW/cm^2.

b. Microwave Reception Effectiveness. - The minimum concentration of fungi per gram of soil to give 10, 50, and 90 percent reductions in number should be ascertained. Also, determine if certain taxonomic groups and fungal structures (sporocarps, mycelia, spores, rhizoids) are more effective conductors than others. The significance of these studies is in the relative importance of fungi as pathogens, saprophytes, and symbionts and whether or not given types will become predominant with acute and chronic exposures. Although no studies of this nature have been made with fungi, some work with nematodes and bacteria, suggests it might be an important area for research. Barker et al. (56), exposed netatode-containing soil to 2450 MHz, 630 W for 2-5 minutes. Some nematodes (*Meloidogyne incognita*) were easily

VIII. MYCOLOGY - EFFECTS OF CW 2.45 GHz MICROWAVES ON FUNGI*

SIGNIFICANCE OF CATEGORY

The safe development of a microwave power transmission system requires that potentially hazardous environmental and biological effects be identified and characterized. These effects should be determined and quantified for a broad range of biological interactions within various ecosystems so that environmentally acceptable power densities are known. Fungi have a significant role in terrestrial ecosystems. They have evolved complex interactions with other microorganisms and vascular plants that affect plant health and thereby productivity of agricultural crops. They serve as disease agents, as antagonists of disease agents, as vehicles for transmission of viruses, and as biological control agents. They provide delectable eating but also devour man's crops.

Subtle changes in the environment can cause marked effects in these interactions. Changes in temperature, water potential, oxygen diffusion rates, and nutrition can cause fluctuations in species number and composition completely upsetting the biological balance. Those changes may stimulate growth of one fungus but retard or inhibit growth of an associate; they may stimulate the formation of resting spores of one fungus but inhibit formation in an associate; they can stimulate or inhibit the formation of mycorrhizal relationships vital to growth of conifers and other crops, and they may affect the rate of decomposition of organic matter and phytotoxins. It is conceivable that microwave power transmission could alter the biological balance so that regulatory mechanisms that maintain order in fungal eco-systems no longer are synchronous. The result would be interactions leading to plant disease.

*Abstracted from Reports 1 and 2 "Assessment of the Effects of Microwave Transmission on Fungi", prepared for the Biosystems Division, Ames Research Center, NASA, by James R. Burleigh, California State University, Chico, California, August, 1977

killed but others (*Heterodera glycines*) were extremely resistant; the difference probably was due to differences in the structure of the cysts. Hankin and Sands (57) irradiated tobacco seed infested with the bacterium *Erwinia carotovora* with 2450 MHz, 625 W for 20 minutes. That frequency and dose killed the bacteria but did not harm the tobacco seed. Those findings show the differential effects of microwaves on biological material and imply that differential effects between species of fungi are to be expected.

c. <u>Changes in Species Number and Diversity as a Function of Power-Depth Penetration of Microwaves.</u> - Determine interrelation between power-depth, soil type, soil moisture content and change in species number and diversity. The significance of this task is that some pathogenic soil fungi predominate near the soil surface (*Rhizoctonia* sp., *Sclerotium* sp.), while others predominate at 1-3 m (*Phymatotrichum* sp., *Pythium* sp., and *Phytophthora* sp.) (58). Also, mycorrhizal fungi act as biological deterrents to pathogenic root infections and those fungi naturally function in the root zone of plants (59). Research should determine population changes in those and other pathogenic and symbiotic fungi as a function of power density at various depths. The depth microwaves will penetrate soil decreases exponentially ($e^{-\alpha\chi}$) with the attenuation factor (α) which is a characteristic of a particular soil and depth (χ). From those calculations the increase in temperature of a material per unit time, ΔT, is given by $\Delta T = P/C_{\rho}$ (60); where P is the power in watts/cm^3, C is the specific heat of the material (cal/cm^3) and ρ is the density of the material. Most soils have a specific heat of 0.198 to 0.267 and density values of approximately 1.4 g/cm^3 (61). Since dry soils are poor heat conductors (62), there should be an inverse relation between moisture content and penetration depth by microwaves. Also soil composition and porosity will affect heat movement. Conductivity decreases as porosity increases; therefore, sand is a better conductor than loam, and loam is better than clay.

d. <u>Regulation of Antagonistic and Symbiotic Interactions of Fungal Ecosystems.</u> - The response of biological control systems in fungi, and formation of mycorrhizal relationships to microwaves, should be studied to determine effects caused by acute and chronic

doses. The significance of this task is that many critical relationships (antibiosis, competition and hyperparasitism) exist between genera of soil fungi that naturally limit growth and development of important root-invading fungi. The successful establishment and maintenance of those relationships are, in large part, dependent on soil factors (moisture content, pH, oxygen content, nutrients, plant-root exudates, ethylene production) directly or indirectly affected by temperature (58,63,64). Mycorrhizal symbiosis is a phenomenon associated with forest trees and a large number of agricultural plants. The benefit from ectomycorrhizae is by (a) absorption of inorganic and organic nutrients, (b) addition of growth-regulating substances, (c) antibiosis of root pathogens and d) host resistance to drought (65,63). To avoid disruption of the delicate balance existing in mycorrhizal cymbiosis, research should establish dose and dose rate responses of selected examples that might serve as models for extrapolation of information.

2. <u>WHAT ALTERATION IN NORMAL RESPONSES OF FUNGI TO STRESS ARE EVOKED BY EXPOSURE TO CW 2.45 GHz MICROWAVES?</u>

a. <u>Stress Changes.</u> - Experiments should be designed to determine the effects of acute and chronic doses of microwave illumination on the ability of facultative fungal pathogens to invade and colonize plants under stress. Normally, facultative pathogens are weak parasites and persist as saprophytes. They may establish and maintain a non-pathogenic relationship with vigorously growing plants until the environment becomes unfavorable for the host. Plant damage, commonly referred to as disease, then appears, often rapidly. Around antennae, plants and soil will be exposed to various power densities of microwave illumination. Experiments should be conducted to determine if facultative pathogens in the rhizosphere of stressed plants will become pathogenic - thereby creating new and unsuspected disease problems. Initially, such experiments should be designed to study the effects of microwaves on water potential in the rhizosphere and concommitant changes in mycelial growth, spore germination, spore discharge and infectivity of selected fungi. Water potential is a measure of the capacity of water to do work,

compared with the work of pure, free water at the same temperature. Power densities within the range anticipated around microwave receiving antennae might cause increases in soil temperature. As a consequence, resistance to water flow from soil to plants will be decreased, and the water potential will decrease (66). Some fungi are favored by dry soils (67) and, therefore, may become pathogenic to crops near the antennae.

b. Indirect Thermal Effects. - The energy of microwaves near the receiving antennae, most likely will be evident as an increase in temperature, dependent on power density and heat radiation from soil. Periodic application of moisture as dew or rain, and from irrigation and its evaporation, however, might compensate for temperature increase. Nevertheless, indirect thermal effects also should be explored, in that periodic temperature increases will cause changes in soil water potential, soil oxygen concentration, and phytoalexin production in plants. Each of those indirect effects will alter species number and composition and to some extent, pathogenicity by predisposing plants to damage by fungi (68). Experiments should be done to determine the effect of microwave illumination on two of the most important indirect thermal responses: soil oxygen diffusion rates, and changes in natural defense mechanisms in plants through phytoalexin formation.

The combined effects of microwaves and periodic applications of moisture may cause temperature fluctuations which, in turn, will cause changes in oxygen diffusivity into soils. The fact that fungi, with the exception of a few species, consume free oxygen makes the importance of this element second only to food supply. Experiments should be conducted to determine the distribution and species composition of fungi in soil profiles, as a function of microwave penetration depth, power density and oxygen diffusion rate (ODR). There are marked differences in the distribution and species composition of fungi in soil profiles as a result of oxygen concentration (69). Studies by Klotz et al. (70,71), showed significant differences in mycelial growth and spore germination of *Phytophthora parasitica*, *P. citrophthora*, and *Thielaviopsis basicola* when subjected to various oxygen concentrations. More importantly, Stolzy et al. (72) reported a decrease

in disease potential of *Phytophthora* species with changes in ODR. That changes in species composition will occur with changes in ODR seems well documented. The significance of this task then, is in the determination of effects microwaves have on oxygen diffusivity into soils.

c. Natural Defense Mechanisms. - Changes in the ability of plants to resist damage by soil and aerial fungi should be studied as a function of microwave illumination. Dose response curves of induced resistance to acute and chronic exposures should be determined for selected host:parasite systems. Also, it should be determined if such responses are frequency dependent. Phytoalexins are, for the most part, phenolic compounds and not part of a rigid matrix. As such, they may be subject to molecular resonances which affect their function in resistance to fungi. The rationale for this study is that one important mechanism of plant resistance to damage by fungi, involves the infection of host plants by avirulent pathogens which cause the induction of chemical inhibitors, called phytoalexins. Reports in the literature (73,74) suggest that suppression or reduction of phytoalexin formation, caused by rather modest temperatures (47° for 30 minutes), predisposed host plants to damage by fungi.

d. Formation of Fungal Propagules Resistant to Environmental Extremes. - The response of soil fungi to warming of the soil surface will be to form spores or vegetative structures resistant to environmental extremes. Experiments should be conducted to determine the rate of formation of resistant structures as a function of microwave power density, penetration depth of microwave illumination, and temperature increase.

e. Changes in Resident and Transient Populations of Fungi on Leaf Surfaces. - Changes in the fungal composition of leaf surfaces have significant implications for the stability of plant and crop systems. Antagonistic interactions among genera of fungi are, in part, responsible for the healthfulness, of many agricultural plants (58). Therefore, the performance of several of these ecosystems should be studied to determine changes in transient and resident populations, as a function of microwave dose.

3. WHAT ARE THE THERMAL EFFECTS OF ABSORBED CW 2.45 GHz MICROWAVES ON SOIL?

a. Physical Measurements. - Preliminary calculations indicate that penetration increases as water content decreases. In areas of high microwave impact, temperature could increase significantly, and an ecological change could be evoked by effects on soil-dependent microorganisms and lower order plants. Even at the periphery of the rectenna, soil temperatures could be elevated under some circumstances. Establishing the changes from microwave illumination in soil temperature and water content, will then allow predictions to be made about changes in bacteria populations from existing data.

PLANNING CHARTS

6.0.0.0. MYCOLOGY

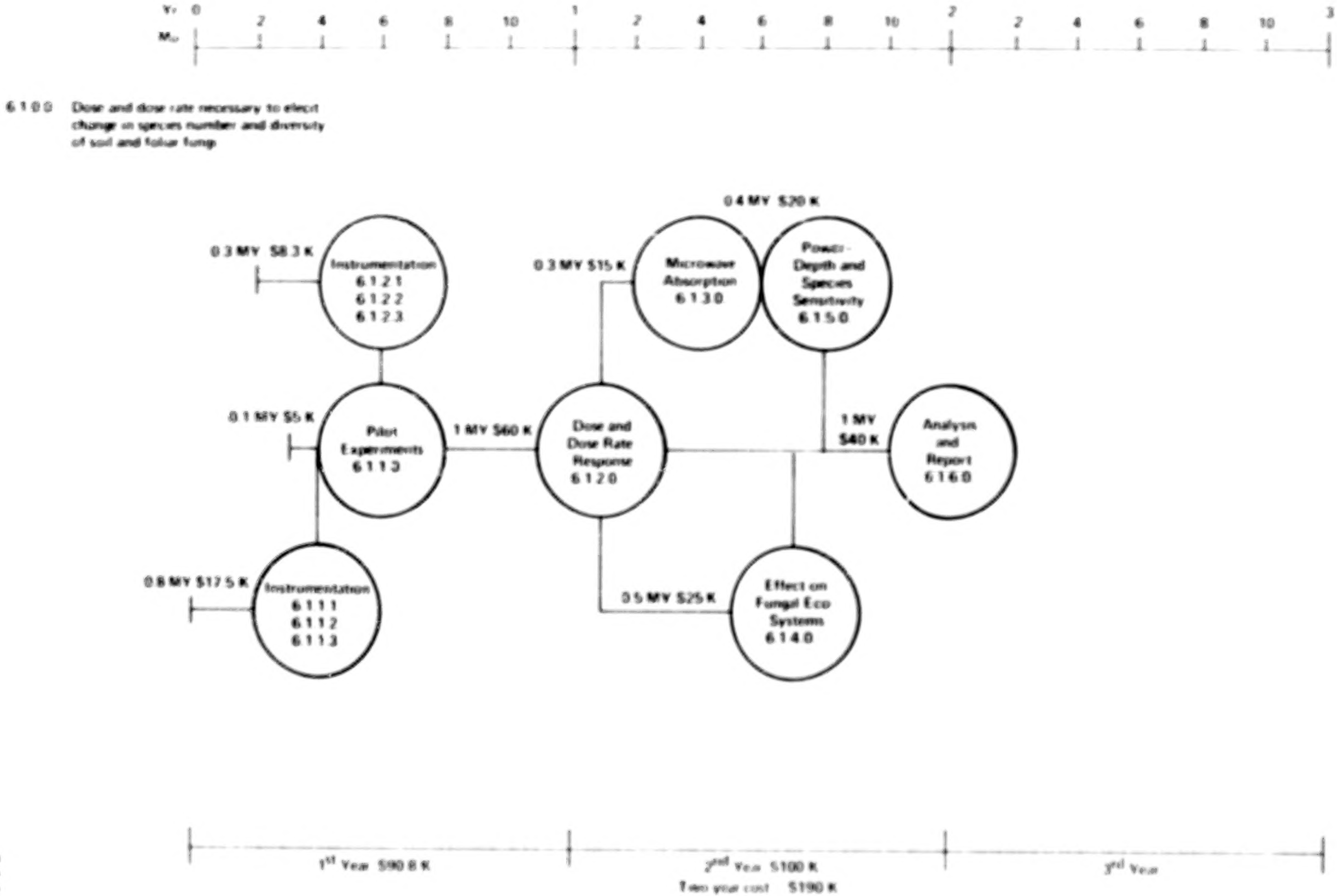

Figure 22

6.0.0.0 MYCOLOGY

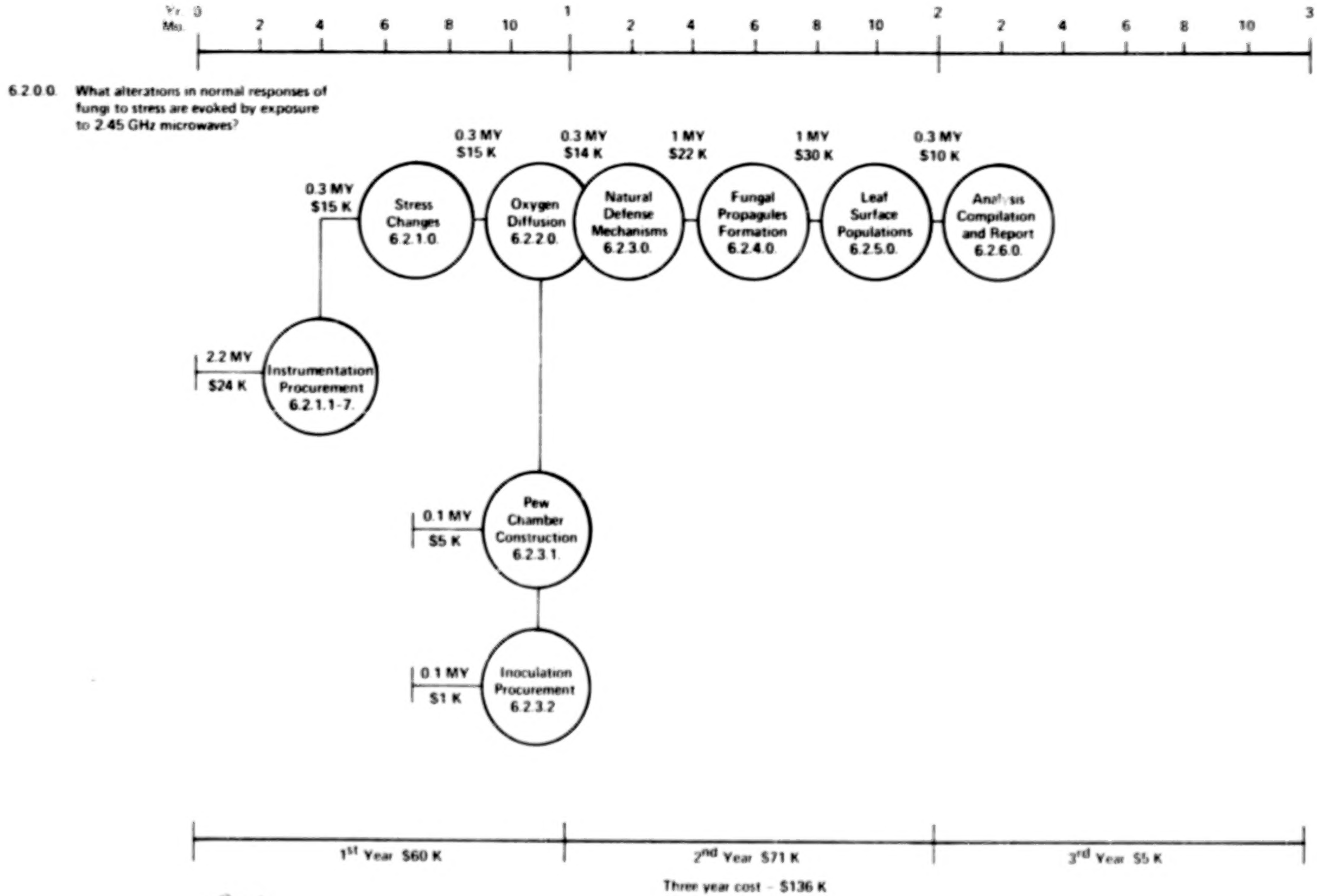

Figure 23

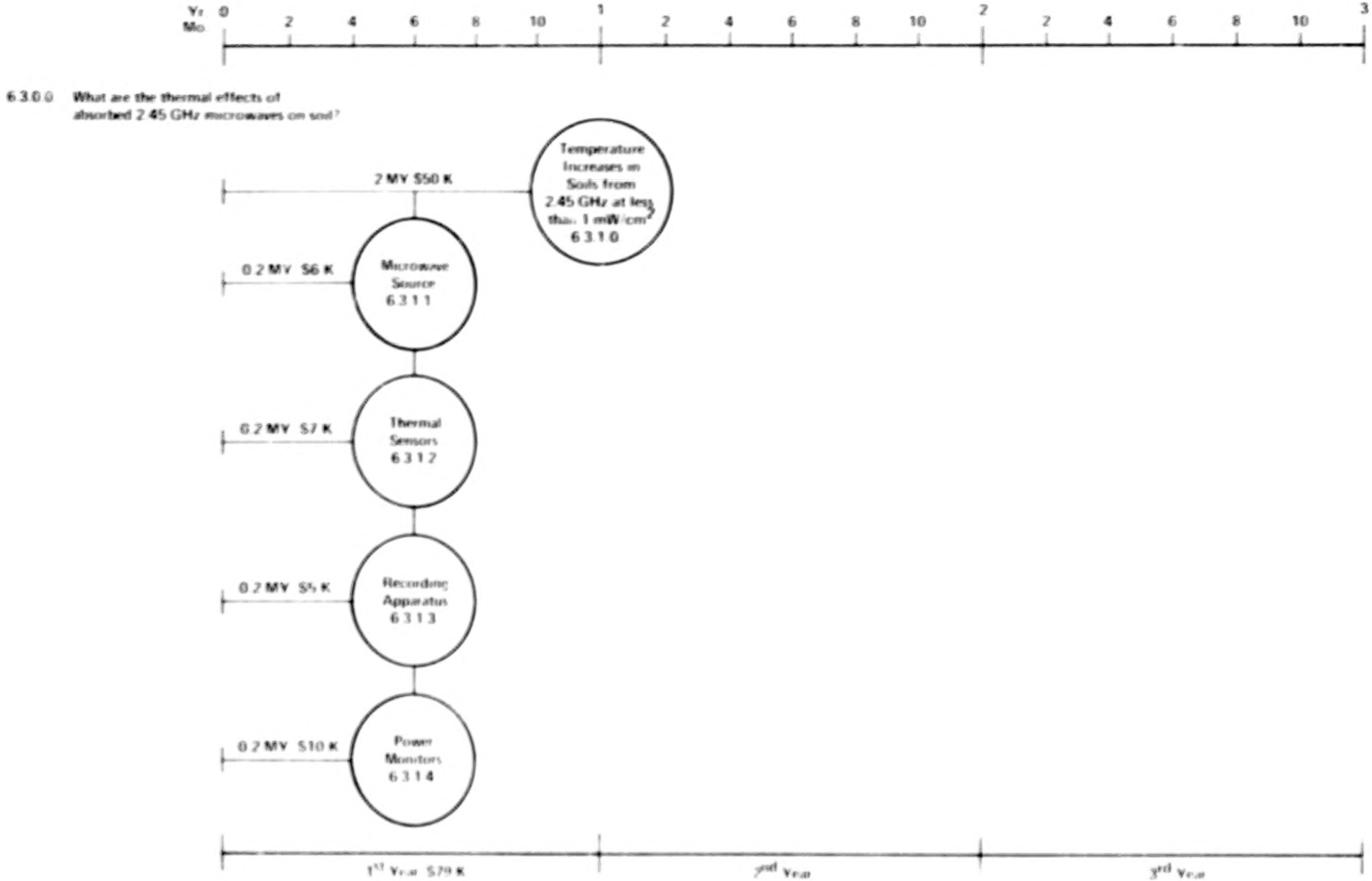

Figure 24

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PROTOCOLS

TABLE 109

6.1 DOSE AND DOSE RATE NECESSARY TO ELICIT CHANGES IN SPECIES, NUMBER AND DIVERSITY OF SOIL AND FOLIAR FUNGI

PROTOCOL 6.1.1.0 PILOT EXPERIMENTS

- HYPOTHESIS OR TASK: MICROWAVES AT 2.45 GHz CW WILL CAUSE A TEMPERATURE RISE IN FUNGI AND AFFECT GROWTH, VIABILITY AND STRUCTURE.
- APPROACH: EXPOSE SELECTED FUNGI TO DOSE AND DOSE RATES EXPECTED TO CAUSE A TEMPERATURE INCREASE. MEASURE QUANTITY OF HEAT THAT MUST BE APPLIED TO RAISE TEMPERATURE OF FUNGAL STRUCTURES AND RECORD ATTENDANT CHANGES IN SPORE PRODUCTION AND GERMINATION.
- INFORMATION TO BE DERIVED: DOSE AND DOSE RATES REQUIRED TO AFFECT FUNGAL STRUCTURE AND GROWTH.
- EXPERIMENT TIME:
  - MONTHS TO COMPLETE 3
  - MAN YEARS 0.1
- COST FOR RESEARCH: $5K
- NEW FACILITIES REQUIRED:

	TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
6.1.1.1	MICROWAVE SOURCES	$12K	0.2	4 MONTHS
6.1.1.2	ANECHOIC CHAMBER	$1.5K	0.5	3 MONTHS
6.1.1.3	TEMPERATURE PROBES & RECORDER	$4K	0.1	3 MONTHS

TABLE 110

6.1 DOSE AND DOSE RATE NECESSARY TO ELICIT CHANGES IN SPECIES, NUMBER AND DIVERSITY OF SOIL AND FOLIAR FUNGI

PROTOCOL 6.1.2.0 DOSE AND DOSE RATE EXPERIMENTS

- HYPOTHESIS OR TASK: THE EFFECTS OF MICROWAVES ON FUNGI ARE A FUNCTION OF DOSE BUT ALSO MAY BE A FUNCTION OF DOSE RATE, SOIL TEXTURE, SOIL MOISTURE, AND TAXONOMIC POSITION OF THE FUNGUS.
- APPROACH: SEED FUNGI SELECTED FROM ALL MAJOR TAXA ONTO SOILS THAT DIFFER IN TEXTURE AND MOISTURE CONTENT. IRRADIATE SOIL WITH PREDETERMINED DOSAGES AND DOSE RATES OF 2.45 GHz MICROWAVES CW. AFTER EXPOSURE, CULTURE FUNGI ON SELECTIVE MEDIA AND RECORD SPECIES NUMBER AND DIVERSITY. GENERATE REGRESSION EQUATIONS WITH SPECIES NUMBER AS THE DEPENDENT VARIABLE AND ENVIRONMENTAL FACTORS AS INDEPENDENT VARIABLES.
- INFORMATION TO BE DERIVED: CHANGES IN SPECIES NUMBER AND DIVERSITY AS A FUNCTION OF DOSE, DOSE RATE, SOIL TEXTURE, SOIL MOISTURE AND TAXONOMIC POSITION.
- EXPERIMENT TIME:

MONTHS TO COMPLETE	7
MAN YEARS	1

- COST FOR RESEARCH: $60K
- NEW FACILITIES REQUIRED:

	TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
6.1.2.1	MULTICHANNEL TEMPERATURE RECORDER AND THERMOCOUPLES	$5K	0.1	4 MONTHS
6.1.2.1	LUCITE TUBES	$0.3K	---	1 MONTH
6.1.2.3	INCUBATORS (2)	$3K	0.2	4 MONTHS

TABLE 111

6.1 DOSE AND DOSE RATE NECESSARY TO ELICIT CHANGES IN SPECIES, NUMBER AND DIVERSITY OF SOIL AND FOLIAR FUNGI

PROTOCOL 6.1.3.0 MICROWAVE ABSORPTION

- HYPOTHESIS OR TASK: THERE IS A MINIMUM CONCENTRATION OF FUNGI PER GRAM OF SOIL NECESSARY TO ABSORB AND CONDUCT MICROWAVES. FUNGAL STRUCTURES DIFFER IN THEIR RECEPTION EFFECTIVENESS AND CONDUCTANCE.
- APPROACH: EXPOSE SELECTED CONCENTRATIONS OF FUNGI AND FUNGAL STRUCTURES TO MICROWAVES AND GENERATE PREDICTIVE EQUATIONS WITH CONCENTRATION AND STRUCTURAL GEOMETRY AS DEPENDENT VARIABLES AND DOSE AND DOSE RATE AS INDEPENDENT VARIABLES.
- INFORMATION TO BE DERIVED: THE MINIMUM, OPTIMUM AND MAXIMUM CONCENTRATIONS OF FUNGAL STRUCTURES BEST SUITED FOR ABSORBANCE AND CONDUCTANCE OF 2.45 GHz.
- EXPERIMENT TIME:

MONTHS TO COMPLETE	3
MAN YEARS	.3

- COST FOR RESEARCH: $15K
- NEW FACILITIES REQUIRED:

TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
COMMON WITH 6.1.1.0 AND 6.1.2.0			

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TABLE 112

6.1 DOSE AND DOSE RATE NECESSARY TO ELICIT CHANGES IN SPECIES, NUMBER AND DIVERSITY OF SOIL AND FOLIAR FUNGI

PROTOCOL 6.1.4.0 REGULATION OF ANTAGONISTIC AND SYMBIOTIC INTERACTIONS IN FUNGAL ECOSYSTEMS

- HYPOTHESIS OR TASK: FUNGI SHOW A DIFFERENTIAL RESPONSE TO MICROWAVES. THEREFORE, FUNGAL ECOSYSTEMS WILL BE DISTURBED AND SOME FUNGI WILL BECOME PREDOMINATE WHILE OTHERS DIMINISH IN NUMBER.
- APPROACH: DETERMINE THE EFFECTS OF MICROWAVES ON FUNGAL ANTIBIOSIS, COMPETITION, HYPERPARASITISM, AND ESTABLISHMENT OF MYCORRHIZAE BY IRRADIATING ECOSYSTEMS AND DETERMINING CHANGES IN SPECIES COMPOSITION.
- INFORMATION TO BE DERIVED: THE EFFECT OF MICROWAVES ON BIOLOGICAL CONTROL MECHANISMS OPERATIVE IN FUNGAL ECOSYSTEMS.
- EXPERIMENT TIME:
  - MONTHS TO COMPLETE 6
  - MAN YEARS .5
- COST FOR RESEARCH: $25K
- NEW FACILITIES REQUIRED:

TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
COMMON WITH 6.1.1.0 AND 6.1.2.0			

TABLE 113

6.1 DOSE AND DOSE RATE NECESSARY TO ELICIT CHANGES IN SPECIES, NUMBER AND DIVERSITY OF SOIL AND FOLIAR FUNGI

PROTOCOL 6.1.5.0 CHANGES IN SPECIES NUMBER AND DIVERSITY AS A FUNCTION OF POWER-DEPTH PENETRATION OF MICROWAVES

- HYPOTHESIS OR TASK: THE POWER DENSITY OF MICROWAVES AT ANY DEPTH IS A FUNCTION OF SOIL TEXTURE AND MOISTURE AND CHANGES IN SPECIES NUMBER AND COMPOSITION OF FUNGI WITH DEPTH IS A FUNCTION OF THE POWER DENSITY AT THAT DEPTH.
- APPROACH: MIX SELECTED FUNGI AND STERILE SOIL AND PLACE IN ONE METER LUCITE TUBES. EXPOSE TO SELECTED DOSE AND DOSE RATES, THEN CULTURE FUNGI FROM SOIL AND RECORD SPECIES NUMBER AND COMPOSITION. FIT DATA TO MULTIPLE REGRESSION EQUATION.
- INFORMATION TO BE DERIVED: CHANGES IN NUMBER OF FUNGAL PROPAGULES AND NUMBER OF SPECIES AS A FUNCTION OF SOIL DEPTH POWER DENSITY AND TEMPERATURE.
- EXPERIMENT TIME:

MONTHS TO COMPLETE	4
MAN YEARS	.4

- COST FOR RESEARCH: $20K
- NEW FACILITIES REQUIRED:

TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
COMMON WITH 6.1.1.0 AND 6.1.2.0			

TABLE 114

6.1 DOSE AND DOSE RATE NECESSARY TO ELICIT CHANGES IN SPECIES, NUMBER AND DIVERSITY OF SOIL AND FOLIAR FUNGI

PROTOCOL 6.1.6.0 ANALYSIS AND REPORT

- HYPOTHESIS OR TASK: PREPARE FINAL REPORT
- APPROACH: COMPILE RESULTS OF EXPERIMENTS 6.1.1.0 THROUGH 6.1.5.0. ANALYZE AND PREPARE FINAL REPORT. REPEAT QUESTIONABLE DATA POINTS.
- INFORMATION TO BE DERIVED: ANSWER TO QUESTION 6.1.
- EXPERIMENT TIME:
  - MONTHS TO COMPLETE 9
  - MAN YEARS 1
- COST FOR RESEARCH: $40K
- NEW FACILITIES REQUIRED:

TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
NONE			

TABLE 115

6.2 WHAT ALTERATIONS IN NORMAL RESPONSES OF FUNGI TO STRESS ARE EVOKED BY EXPOSURE TO 2.45 GHz MICROWAVES?

PROTOCOL 6.2.1.0 STRESS CHANGES

- HYPOTHESIS OR TASK: MICROWAVES WILL HEAT SOIL AND CREATE NEGATIVE WATER POTENTIALS IN THE RHIZOSPHERE, THEREBY STRESSING PLANTS AND PREDISPOSING THEM TO ATTACK FUNGI.
- APPROACH: IRRIGATE SOIL, INOCULATE WITH SELECTED FUNGI, THEN IRRADIATE AT PREDETERMINED DOSES AND DOSE RATES. RECORD TEMPERATURE, WATER POTENTIAL AND FUNGAL GROWTH, AND EXPRESS FUNGAL GROWTH AS A FUNCTION OF DOSE, DOSE RATE, AND WATER POTENTIAL. PLANT IN IRRADIATED SOIL CROP PLANTS SUSCEPTIBLE TO THE EXPERIMENTAL FUNGI. OBSERVE PLANTS FOR SIGNS AND SYMPTOMS OF DISEASE. EXPRESS AMOUNT OF DISEASE AS A FUNCTION OF WATER POTENTIAL.
- INFORMATION TO BE DERIVED: NUMERICAL ANALYSIS OF THE EFFECTS OF MICROWAVES ON WATER POTENTIAL OF PLANTS AND SOIL AND SUBSEQUENT CHANGES IN DISEASE PRONENESS.
- EXPERIMENT TIME:

MONTHS TO COMPLETE	3
MAN YEARS	.3

- COST FOR RESEARCH: $15K
- NEW FACILITIES REQUIRED:

	TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
6.2.1.1	MICROWAVE GENERATOR & WAVEGUIDE	$12K	0.2	4 MONTHS
6.2.1.2	ANECHOIC CHAMBER	$3K	0.5	3 MONTHS
6.2.1.3	INCUBATORS	$3K	0.2	4 MONTHS
6.2.1.4	FUNGAL CULTURES	$.3K	0.5	2 MONTHS
6.2.1.5	THERMOCOUPLE PSYCHROMETER AND MICROVOLTMETER	$2K	0.2	4 MONTHS
6.2.1.6	TEMPERATURE MONITORING SYSTEM	$4K	0.2	4 MONTHS
6.2.1.7	OXYGEN ANALYZER	$1.5K	0.2	4 MONTHS

TABLE 116

6.2 WHAT ALTERATIONS IN NORMAL RESPONSES OF FUNGI TO STRESS ARE EVOKED BY EXPOSURE TO 2.45 GHz MICROWAVES?

PROTOCOL 6.2.2.0 INDIRECT THERMAL EFFECTS - OXYGEN DIFFUSION RATES

- HYPOTHESIS OR TASK: THERMAL EFFECTS OF MICROWAVES WILL INCREASE OXYGEN DIFFUSION INTO SOILS AND ALTER SPECIES NUMBER AND COMPOSITION.
- APPROACH: INOCULATE SOILS WITH FUNGI KNOWN TO RESPOND TO SMALL CHANGES IN OXYGEN CONCENTRATION; IRRADIATE SOILS, MONITOR TEMPERATURE AND OXYGEN DIFFUSION RATES. CULTURE FUNGI FROM SOILS AND RECORD SPECIES NUMBER. INTO THE SOIL PREVIOUSLY INOCULATED AND IRRADIATED, SEED CROPS SUSCEPTIBLE TO TEST FUNGI. RECORD DISEASE SEVERITY AS A FUNCTION OF OXYGEN DIFFUSION RATE.
- INFORMATION TO BE DERIVED: THE QUANTITIATIVE EFFECTS OF 2.45 GHz MICROWAVE ON OXYGEN DIFFUSION RATES INTO SOILS AND ACCOMPANYING EFFECTS ON FUNGAL GROWTH AND PATHOGENICITY.
- EXPERIMENT TIME:

MONTHS TO COMPLETE	4
MAN YEARS	.3

- COST OF RESEARCH: $15K
- NEW FACILITIES REQUIRED:

TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
COMMON WITH 6.2.1.0			

TABLE 117

6.2 WHAT ALTERATIONS IN NORMAL RESPONSES OF FUNGI TO STRESS ARE EVOKED BY EXPOSURE TO 2.45 GH_Z MICROWAVES?

PROTOCOL 6.2.3.0 INDIRECT THERMAL EFFECTS - NATURAL DEFENSE MECHANISMS

- o HYPOTHESIS OR TASK: HOST PLANT DEFENSE MECHANISMS WHICH DEPEND ON PHYTOALEXIN PRODUCTION BY AVIRULENT FUNGI ARE SENSITIVE TO MICROWAVE IRRADIATION.
- o APPROACH: IRRADIATE SELECTED FUNGI AND INFECTED PLANTS WITH PREDETERMINED DOSES OF 2.45 GH_Z MICROWAVES. INOCULATE PLANTS WITH IRRADIATED, AVIRULENT FUNGI AND WITH NONIRRADIATED VIRULENT FUNGI. MEASURE AMOUNT OF DISEASE. INOCULATE SIMILAR PLANTS WITH NONIRRADIATED AVIRULENT FUNGI, IRRADIATE PLANTS THEN INOCULATE WITH NONIRRADIATED VIRULENT FUNGI. DISEASE WOULD SUGGEST LITTLE OR NO PHYTOALEXIN PRODUCTION.
- o INFORMATION TO BE DERIVED: THE EFFECTS OF MICROWAVES ON PHYTOALEXIN PRODUCTION IN PLANTS AND IF THE EFFECTS OCCUR IN THE FUNGUS WHICH INDUCES PHYTOALEXINS OR IN THE STRUCTURE OF THE PHYTOALEXIN.
- o EXPERIMENT TIME:

MONTHS TO COMPLETE	3
MAN YEARS	.3

- o COST FOR RESEARCH: $14K
- o NEW FACILITIES REQUIRED:

	TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
6.2.3.1	DEW CHAMBER	$5K	0.1	4 MONTHS
6.2.3.2	QUANTITATIVE INOCULATOR	$1K	0.1	4 MONTHS

TABLE 118

6.2 WHAT ALTERATIONS IN NORMAL RESPONSES OF FUNGI TO STRESS ARE EVOKED BY EXPOSURE TO 2.45 GH_Z MICROWAVES?

PROTOCOL 6.2.4.0 FORMATION OF FUNGAL PROPAGULES RESISTANT TO ENVIRONMENTAL EXTREMES

- o HYPOTHESIS OR TASK: MICROWAVES, BY INCREASING SOIL TEMPERATURE, WILL INDUCE FORMATION OF FUNGAL STRUCTURES RESISTANT TO TEMPERATURE, OXYGEN AND MOISTURE EXTREMES, THEREBY ALTERING SPECIES COMPOSITION OF THE SOIL.
- o APPROACH: INOCULATE SOIL WITH FUNGI KNOWN TO PRODUCE RESISTANT STRUCTURES. IRRADIATE SOIL THEN ANALYZE FOR NUMBER OF RESISTANT STRUCTURES AND THEIR VIABILITY. EXAMINE EFFECTS OF MICROWAVES ON COLONIZATION OF PYTHIUM SP. BY RHIZOCTONIA SOLANI.
- o INFORMATION TO BE DERIVED: THE RATE OF FORMATION OF FUNGAL PROPAGULES RESISTANT TO ENVIRONMENTAL EXTREMES AS A FUNCTION OF MICROWAVE DOSE.
- o EXPERIMENT TIME:

MONTHS TO COMPLETE	4
MAN YEARS	1

- o COST FOR RESEARCH: $22K
- o NEW FACILITIES REQUIRED:

TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
COMMON WITH 6.2.1.0 AND 6.2.3.0			

TABLE 119

6.2 WHAT ALTERATIONS IN NORMAL RESPONSES OF FUNGI TO STRESS ARE EVOKED BY EXPOSURE TO 2.45 GH_Z MICROWAVES?

PROTOCOL 6.2.5.0 CHANGES IN RESIDENT AND TRANSIENT POPULATIONS OF FUNGI ON LEAF SURFACES

- o HYPOTHESIS OR TASK: MICROWAVES WILL AFFECT FUNGAL ECOSYSTEMS ON LEAF SURFACES BY DISRUPTING BIOLOGICAL CONTROLS.
- o APPROACH: IRRADIATE SELECTED DISEASED MATERIAL AND HYPERPARASITES. RECORD CHANGE IN PERCENT COLONIZATION.
- o INFORMATION TO BE DERIVED: EFFECTS OF MICROWAVES ON INTERACTIONS OF TRANSIENT AND RESIDENT FUNGI WITH PLANT PATHOGENS.
- o EXPERIMENT TIME:

MONTHS TO COMPLETE	4
MAN YEARS	1

- o COST FOR RESEARCH: $30K
- o NEW FACILITIES REQUIRED:

TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
COMMON WITH 6.2.1.0 AND 6.2.3.0			

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TABLE 120

6.2 WHAT ALTERATIONS IN NORMAL RESPONSES OF FUNGI TO STRESS ARE EVOKED BY EXPOSURE TO 2.45 GHz MICROWAVES?

PROTOCOL 6.2.6.0 ANALYSIS AND REPORT

- HYPOTHESIS OR TASK: PREPARE A REPORT ON THE RESULTS OF THE EXPERIMENTS IN 6.2.0.0
- APPROACH: ANALYZE, REPEAT EXPERIMENTS WHERE NECESSARY AND REPORT THE RESULTS OF THE EXPERIMENT INCLUDED IN 6.2.0.0.
- INFORMATION TO BE DERIVED: REPORT THE ALTERATIONS (IF ANY) IN THE NORMAL RESPONSES OF FUNGI TO STRESS WHEN EXPOSED TO 2.45 GHz MICROWAVES.
- EXPERIMENT TIME:

MONTHS TO COMPLETE	4
MAN YEARS	.3

- COST FOR RESEARCH: $10K
- NEW FACILITIES REQUIRED:

TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
NONE			

TABLE 121

6.3 WHAT ARE THE THERMAL EFFECTS OF ABSORBED 2.45 GHz MICROWAVES ON SOIL?

PROTOCOL 6.3.1.0 IRRADIATION OF SOIL AT VARIOUS POWER DENSITIES

- HYPOTHESIS OR TASK: ESTABLISH TEMPERATURE INCREASE IN SOILS DUE TO MICROWAVE IRRADIATION AT VARIOUS POWER DENSITIES; RELATE SOIL MOISTURE AND ORGANIC CONTENT TO TEMPERATURE INCREASES CAUSED BY MICROWAVE ABSORPTION; ESTABLISH AMOUNT OF MICROWAVE GENERATED HEAT RE-RADIATED AS INFRARED, AS A FUNCTION OF SUB-SURFACE DEPTH OF THE ABSORBER; ANALYZE AND REPORT RESULTS.
- APPROACH: ILLUMINATE SOILS OF VARIOUS MOISTURE AND ORGANIC CONTENT WITH 2.45 GHz IN AN INSULATED CHAMBER AT POWER DENSITIES FROM 0.1 TO 1.0 mW/cm^2). AT SELECTED DEPTHS RADIO-TRANSPARENT SENSORS WILL DETECT TEMPERATURE CHANGES WITH TIME. PERIODIC SAMPLING WILL DETERMINE CHANGES IN MOISTURE CONTENT WITH DEPTH. POWER BALANCE TECHNIQUES WILL BE USED TO DETERMINE RE-RADIATION RATES, OR A COMBINATION OF BROAD BAND SENSORS WILL BE USED TO CALCULATE MICROWAVE REFLECTION OR INFRARED RE-RADIATION RATES.
- INFORMATION TO BE DERIVED: DETERMINE THERMAL ACTIVATION OF SOIL DUE TO BOUND WATER ABSORPTION OF 2.45 GHz MICROWAVES AND RE-RADIATION RATES. POTENTIAL DISTURBANCE TO SOIL MICROORGANISMS, AND THE CONSEQUENT ECOLOGICAL PERTURBATION, WILL BE POSTULATED.
- EXPERIMENT TIME:

MONTHS TO COMPLETE	12
MAN YEARS	2

- COST FOR RESEARCH: $50K
- NEW FACILITIES REQUIRED:

	TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
6.3.1.1	MICROWAVE SOURCE	$ 6K	0.2	4 MONTHS
6.3.1.2	THERMAL SENSORS	$ 7K	0.2	6 MONTHS
6.3.1.3	RECORDING APPARATUS	$ 5K	0.2	1 MONTH
6.3.1.4	FREQUENCY AND POWER MONITORS	$10K	0.2	3 MONTHS

MILESTON'. AND FUNDING SUMMARY

TABLE 122

MILESTONE AND FUNDING SUMMARY

	PHASE A YEAR				COST $K		
	0	1	2	3	Exper.	Facil.	Question
6.1.0.0 Dose and Dose Rate			▽		--	---	191
6.1.1.0 Pilot Experiments	▽				5	18	
6.1.2.0 Dose Response			▽		60	8	
6.1.3.0 Microwave Absorption			▽		15	---	
6.1.4.0 Ecosystems			▽		25	---	
6.1.5.0 Species Sensitivity			▽		20	---	
6.1.6.0 Analysis and Report			▽		40	---	
6.2.0.0 Altered Stress Response				▽	--	---	136
6.2.1.0 Stress Changes		▽			15	24	
6.2.2.0 Oxygen Diffusion		▽			15	---	
6.2.3.0 Defense Mechanisms			▽		14	6	
6.2.4.0 Propagule Formation			▽		22	---	
6.2.5.0 Leaf Surface Population			▽		30	---	
6.2.6.0 Analysis and Report				▽	10	---	

TABLE 122. - Concluded

	PHASE A YEAR				COST $K		
	0	1	2	3	Exper.	Facil.	Question
6.3.0.0 Thermal Effect on Soil		∇			--	---	78
6.3.1.0 Temperature Increase		∇			50	28	

PILOT EXPERIMENTATION

None performed.

IX. EFFECTS OF CHRONIC LOW-LEVEL CW 2.45 GHz ILLUMINATION ON PLANT GROWTH AND DEVELOPMENT*

SIGNIFICANCE OF CATEGORY

The effects of CW 2.45 GHz microwave illumination on biological organisms and the environment, in general, is little understood. This is particularly evident when one considers effects of microwave illumination on plants. The literature contains a paucity of information on plant-microwave interactions and much of the available data is not applicable to predicting microwave impact on plant communities. Early research was designed primarily to determine gross thermal effects and most initial power densities were in excess of 100 mW/cm^2. Relationships between incident and absorbed microwave energy and associated changes in plant temperatures are virtually unknown. Rates of microwave energy absorption and morphophysiological characteristics which influence microwave heating have not been determined. No attempts have been made to determine plant response under continuous exposure to low-level microwave illumination over several generations. Non-thermal microwave effects have been suggested but have not been demonstrated experimentally. Thus, there is much to be learned about the impact of microwave illumination on specific plant species and plant communities.

Data currently available on plant-microwave interactions is grossly inadequate for predicting effects of rectenna site operation on plants. Research is needed to provide base-line data for determing effects of various levels of microwave energy on plant assemblages under a spectrum of environmental conditions. The required data, both theoretical and experimental, can then be utilized to model and predict the impact of rectenna site operation on plant associations, regardless of site location. Research should lead to development of environmentally appropriate management programs for vegetational resources in rectenna site areas.

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*From Final Report for Ames Research Center, NASA Contract NAS2-9552, "Research Program Definition for the Study of the Biological and Ecological Effects of Energy Transmission by Microwaves - Effects of Chronic Low-Level 2450 MHz Illumination on Plant Growth and Development", C. H. Ward and J. M. King, Rice University, December, 1977

PRIORITIZED LIST OF QUESTIONS

1. STATEMENT OF QUESTION OR UNKNOWN, PRIORITY 1. USE OF HEAT BALANCE THEORY AND MODELS TO PREDICT THERMAL RESPONSES OF PLANTS TO MICROWAVE ILLUMINATION.

a. Justification. - It is unreasonable, if not impossible, to expose every potential plant inhabitant of rectenna sites to microwave illumination. Thus, in order to make broad predictions of the impact of rectenna site operation on plant associations, it is necessary to develop an alternative to laboratory experimentation for predicting effects of microwave energy on plant communities. Since known plant response to microwave energy is primarily thermal, it should be possible to use existing heat balance principles and equations to develop a mathematical model for predicting microwave induced heat changes in plants. The model can be used to predict thermal responses of individual species and small scale plant assemblages under various microwave energy levels and environmental conditions. After verification of model accuracy, broad range predictions of rectenna site impact on thermal loading in plants can be made. These predictions can be made without knowing exact locations of rectenna sites.

2. STATEMENT OF QUESTION OR UNKNOWN, PRIORITY 2. EFFECTS OF ACUTE MICROWAVE ILLUMINATION ON SELECTED PLANTS.

a. Justification. - Acute testing is necessary to develop dose-response curves based on plant symptomatology associated with short-term exposure to various levels of microwave energy. Such tests are valuable for relatively rapid determinations of energy absorption rates, comparative plant sensitivity to microwaves, and factors (plant morpho-physiological characteristics and environmental parameters) which influence plant susceptibility to thermal loading. Data can be utilized to determine heat-balances in plants resulting from short-term microwave energy fluctuations and will supply information pertinent, but not essential, to adequate resolution of Question 1. This information is necessary for predicting the impact of short-term energy fluctuations, which far

exceed the maximum level of 10 mW/cm^2 specified by the SPS, on thermal loading of plants in rectenna sites. Data derived from acute testing will aid design of a chronic exposure experimental program.

3. STATEMENT OF QUESTION OR UNKNOWN, PRIORITY 3. EFFECTS OF CHRONIC, LOW-LEVEL MICROWAVE ILLUMINATION ON SELECTED PLANTS.

   a. Justification. - Chronic tests are necessary to determine symptomatology and thermal changes in plants under long-term exposure to uniform levels of sub-lethal microwave illumination. Comparative data on growth, physiological, and developmental responses of plants to continuous microwave illumination can be derived from acute and chronic tests. Data can be utilized for making limited predictions of the impact of rectenna site operation on various flora and in management of these sites. Chronic tests will also provide data pertinent, but not essential, to adequate resolution of Question 1.

4. STATEMENT OF QUESTION OR UNKNOWN, PRIORITY 4. NON-THERMAL EFFECTS OF MICROWAVE ILLUMINATION ON PLANTS.

   a. Justification. - Non-thermal microwave effects on organisms have been reported in the literature, but have not been demonstrated conclusively by experimentation. However, the possibility does exist that plants may respond non-thermally to chronic low-level microwave illumination. Such response could either enhance or retard growth, physiological, and developmental processes in plants. If non-thermal effects do exist, they sould be manifest in plants under continuous exposure to the microwave illuminated environments of rectenna sites. Thus, for complete assessment of microwave impact on plants, it is necessary to experimentally determine the existence of non-thermal effects. If non-thermal effects exist, impact on plants must be determined to fully understand and predict plant response to microwave illumination. Experimental procedures will resemble those used in chronic tests, except that groups of plants will be heated by conventional means to simulate temperature levels present in microwave heated

plants. Since answering these rather complex questions requires more than casual, peripheral experimentation, this research project should be separate from the chronic testing program.

PLANNING CHARTS

7.0.0.0. PLANTS

7.1 Use of heat balance theory and models to predict thermal responses of plants to microwave radiation

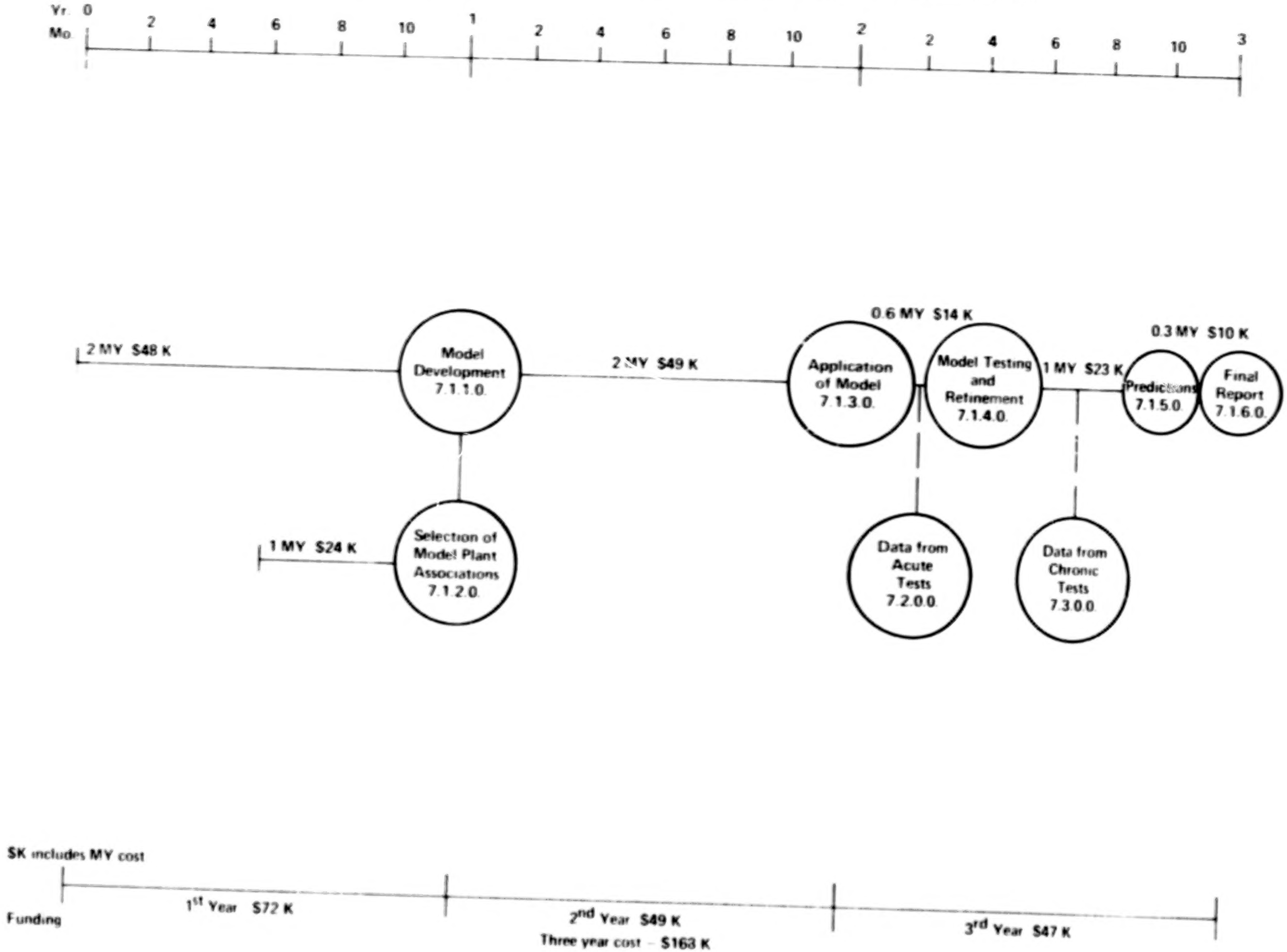

Figure 25

7.0.0.0. PLANTS

7.2 Effects of acute microwave radiation on selected plants

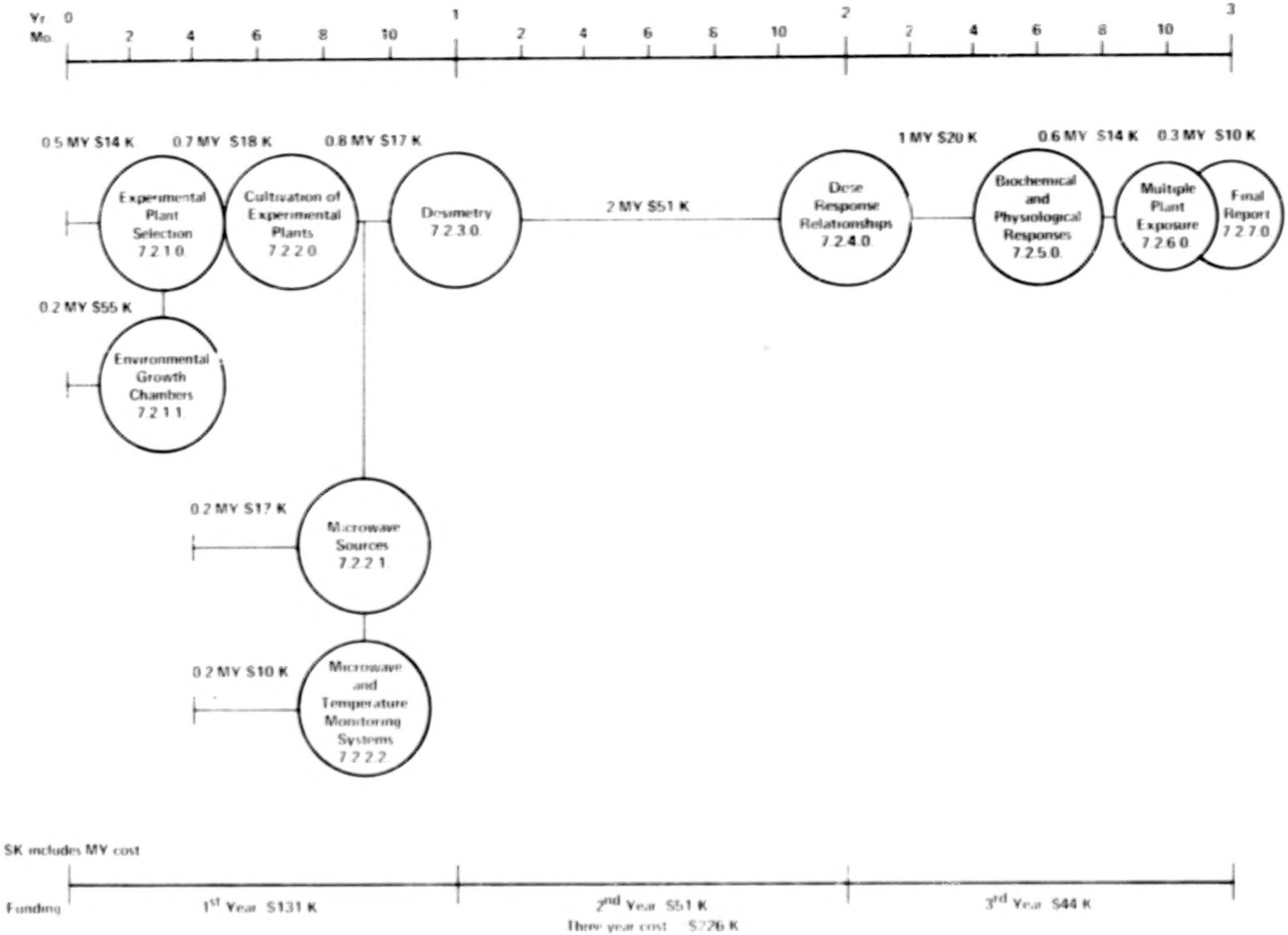

Figure 26

7.0.0.0. PLANTS

7.3. Effects of chronic, low level microwave radiation on selected plants

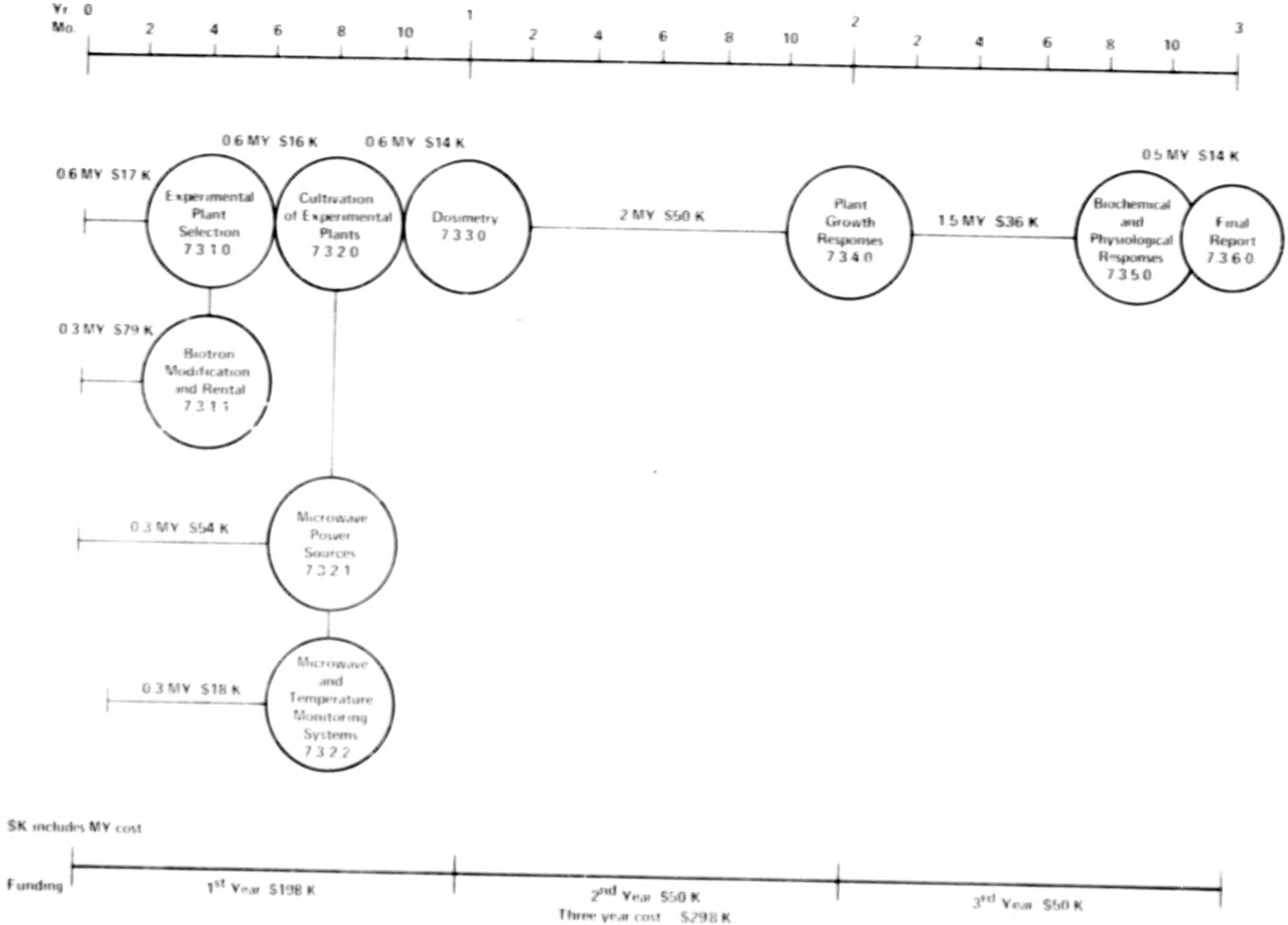

Figure 27

7.0.0.0. PLANTS

7.4. Non thermal effects of microwave radiation on plants

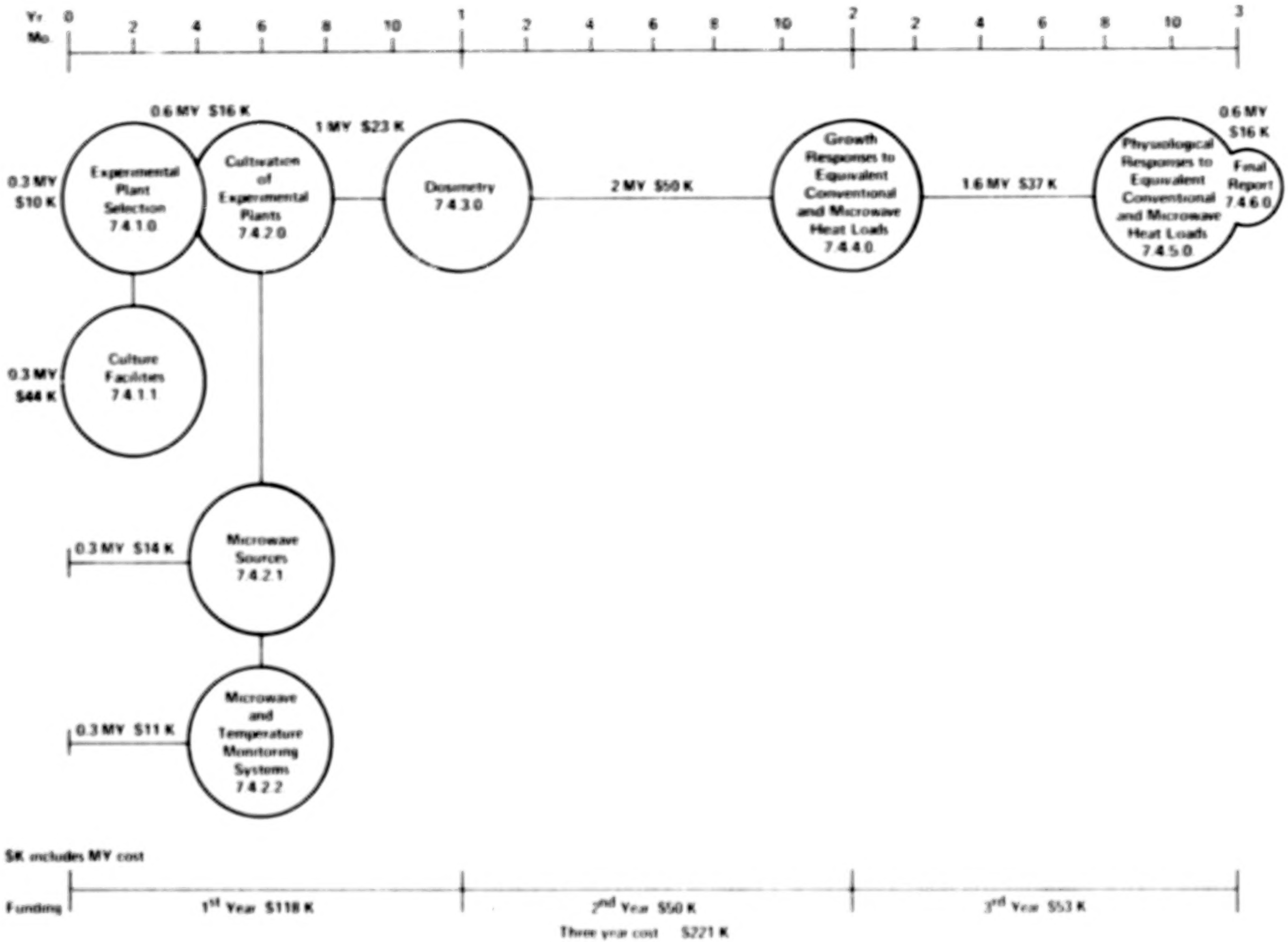

Figure 28

PROTOCOLS

TABLE 123

7.1 USE OF HEAT BALANCE THEORY AND MODELS TO PREDICT THERMAL RESPONSES OF PLANTS TO MICROWAVE RADIATION

PROTOCOL 7.1.1.0 MODEL DEVELOPMENT

- o HYPOTHESIS OR TASK: DEVELOP A MATHEMATICAL MODEL FOR THEORETICAL ANALYSIS OF THERMAL RESONSE OF PLANTS TO MICROWAVE RADIATION AT A FREQUENCY OF 2450 MHz IN A RANGE OF POWER DENSITIES.
- o APPROACH: BIOPHYSICAL PRINCIPLES WHICH EXERT MAJOR INFLUENCE ON HEAT TRANSFER IN PLANTS WILL BE UTILIZED IN MODEL DEVELOPMENT. HEAT BALANCE AND MICROWAVE ABSORPTION EQUATIONS WILL BE INTEGRATED TO FORM A MATHEMATICAL EXPRESSION FOR PREDICTING PLANT RESPONSE TO MICROWAVE ENERGY. A SPECTRUM OF MORPHOLOGICAL AND PHYSIOLOGICAL FACTORS WHICH INFLUENCE THERMAL LOADING IN PLANTS WILL BE EVALUATED AND INCORPORATED INTO THE MODEL.
- o INFORMATION TO BE DERIVED: A MATHEMATICAL MODEL FOR THEORETICAL PREDICTION OF TEMPERATURE CHANGES IN A SPECTRUM OF PLANTS EXPOSED TO MICROWAVE ENERGY UNDER VARIOUS ENVIRONMENTAL CONDITIONS.
- o EXPERIMENT TIME:

MONTHS TO COMPLETE	12
MAN YEARS	2

- o COST FOR RESEARCH: $48K
- o NEW FACILITIES REQUIRED:

TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
NONE			

7.1 USE OF HEAT BALANCE THEORY AND MODELS TO PREDICT THERMAL RESPONSES OF PLANTS TO MICROWAVE RADIATION

PROTOCOL 7.1.2.0 SELECTION OF MODEL PLANT ASSOCIATIONS

- o HYPOTHESIS OR TASK: ESTABLISH MODEL PLANT ASSOCIATIONS WHICH REFLECT MAJOR FLORAL DIVERSITY IN DOMINANT NATURAL AND AGRICULTURAL PLANT ASSOCIATIONS IN THE UNITED STATES.
- o APPROACH: DOMINANT PLANT ASSOCIATIONS IN THE UNITED STATES WILL BE DETERMINED BY USE OF PLANT DISTRIBUTION MAPS AND DATA AVAILABLE IN THE LITERATURE. SPECIES WILL BE SELECTED FROM THESE ASSOCIATIONS FOR USE IN ESTABLISHING MODEL PLANT SYSTEMS COMPOSED OF VARIOUS FLORAL ASSEMBLAGES. PLANTS WILL BE SELECTED ON THE BASIS OF THEIR FREQUENCY OF GEOGRAPHICAL OCCURRENCE AND MAJOR MORPHO-PHYSIOLOGY CHARACTERISTICS (E.G. LEAF SIZE, SHAPE; TRANSPIRATION RATES, ETC.) WHICH INFLUENCE THEIR SENSITIVITY TO THERMAL LOADING.
- o INFORMATION TO BE DERIVED: PLANT SPECIES WHICH MAY BE IMPACTED BY MICROWAVE RADIATION AND THEIR DISTRIBUTIONAL RELATIONSHIPS TO OTHER PLANTS AND ENVIRONMENTAL PARAMETERS WILL BE IDENTIFIED. INFORMATION WILL BE DEVELOPED FOR IDENTIFYING PLANT ASSOCIATIONS WHICH WILL BE EXPOSED TO MICROWAVES REGARDLESS OF GEOGRAPHICAL LOCATION OF SPS RECTENNAE SITES.
- o EXPERIMENT TIME:

MONTHS TO COMPLETE	6
MAN YEARS	1

- o COST FOR RESEARCH: $24K
- o NEW FACILITIES REQUIRED:

TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
NONE			

TABLE 125

7.1 USE OF HEAT BALANCE THEORY AND MODELS TO PREDICT THERMAL RESONSES OF PLANTS TO MICROWAVE RADIATION

PROTOCOL 7.1.3.0 APPLICATION OF MODEL

- o HYPOTHESIS OR TASK: DETERMINE THEORETICAL THERMAL RESPONSES OF SELECTED PLANTS TO SHORT AND LONG-TERM EXPOSURE TO MICROWAVE RADIATION.
- o APPROACH: THE MATHEMATICAL MODEL WILL BE USED TO DETERMINE THERMAL RESPONSES OF SPECIES IN VARIOUS MODEL PLANT ASSOCIATIONS TO SHORT-TERM EXPOSURE TO VARIOUS LEVELS OF MICROWAVE POWER AND TO LONG-TERM EXPOSURE TO THE SPS SPECIFIED MICROWAVE POWER DENSITY OF 10 mW/cm^2).

  PLANT CHARACTERISTICS AND ENVIRONMENTAL CONDITIONS UTILIZED IN THE MODEL WILL REPRESENT THOSE WHICH ARE COMMONLY ENCOUNTERED IN MAJOR PLANT ASSOCIATIONS (NATURAL AND AGRICULTURAL) IN THE UNITED STATES. MODEL PLANT ASSOCIATIONS WILL BE SIMULATED BY USE OF UNI- AND MULTISPECIES ASSEMBLAGES OF PLANTS.
- o INFORMATION TO BE DERIVED: THEORETICAL IMPACT OF MICROWAVE RADIATION ON HEAT BALANCES IN A SPECTRUM OF PLANTS.
- o EXPERIMENT TIME:

MONTHS TO COMPLETE	12
MAN YEARS	2

- o COST FOR RESEARCH: $49K
- o NEW FACILITIES REQUIRED:

TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
NONE			

TABLE 126

7.1 USE OF HEAT BALANCE THEORY AND MODELS TO PREDICT THERMAL RESPONSES OF PLANTS TO MICROWAVE RADIATION

PROTOCOL 7.1.4.0 MODEL TESTING AND REFINEMENT

- HYPOTHESIS OR TASK: TEST MATHEMATICAL MODEL AND MAKE REFINEMENTS NECESSARY TO ENHANCE MODEL EFFECTIVENESS FOR PREDICTING MICROWAVE INDUCED THERMAL CHANGES IN PLANTS AND SELECTED PLANT ASSOCIATION.
- APPROACH: THEORETICAL DATA WILL BE STATISTICALLY COMPARED TO EXPERIMENTAL RESULTS OBTAINED FROM ACUTE TESTS (PERT 7.2) TO EVALUATE THE ACCURACY OF USING THE MODEL TO PREDICT MICROWAVE INDUCED THERMAL CHANGES IN PLANTS. IF NECESSARY, THE MODEL WILL BE REFINED TO ENHANCE PREDICTIVE CAPABILITIES.
- INFORMATION TO BE DERIVED: ACCURACY OF USING THE MATHEMATICAL MODEL TO PREDICT THERMAL CHANGES IN PLANTS EXPOSED TO VARIOUS LEVELS OF MICROWAVE ENERGY.
- EXPERIMENT TIME:

MONTHS TO COMPLETE	4
MAN YEARS	.6

- COST FOR RESEARCH: $14K
- NEW FACILITIES REQUIRED:

TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
NONE			

TABLE 127

7.1 USE OF HEAT BALANCE THEORY AND MODELS TO PREDICT THERMAL RESPONSES OF PLANTS TO MICROWAVE RADIATION

PROTOCOL 7.1.5.0 PREDICTIONS

- HYPOTHESIS OR TASK: PREDICT THE IMPACT OF MICROWAVE RADIATION ON VEGETATION IN MOST PROBABLE RECTENNAE SITES IN THE UNITED STATES.
- APPROACH: THE MATHEMATICAL MODEL WILL BE UTILIZED TO PREDICT THE EFFECTS OF CHRONIC AND VARIABLE MICROWAVE RADIATION ON THERMAL BALANCES IN PLANTS WHICH INHABIT THE MOST PROBABLE RECTENNA SITES IN THE UNITED STATES. EXPERIMENTAL DATA FROM CHRONIC TESTS (PERT 7.3) WILL BE UTILIZED TO EVALUATE ACCURACY OF THEORETICAL PREDICTIONS.
- INFORMATION TO BE DERIVED: THE IMPACT OF CONTINUOUS LOW-LEVEL MICROWAVE RADIATION AND POSSIBLE HIGH-LEVEL ENERGY FLUCTUATIONS ON PLANTS IN FUTURE RECTENNA SITES.
- EXPERIMENT TIME:

MONTHS TO COMPLETE	6
MAN YEARS	1

- COST FOR RESEARCH: $23K
- NEW FACILITIES REQUIRED:

TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
NONE			

TABLE 128

7.1 USE OF HEAT BALANCE THEORY AND MODELS TO PREDICT THERMAL RESPONSES OF PLANTS TO MICROWAVE RADIATION

PROTOCOL 7.1.6.0 FINAL REPORT

- HYPOTHESIS OR TASK: PREPARE A FINAL REPORT FOR THE THREE YEAR RESEARCH PROGRAM. EXISTING THEORY AND MODELLING WILL BE USED TO PREDICT PLANT RESPONSE TO 2450 MHz MICROWAVE ILLUMINATION.
- APPROACH: THE DATA WILL BE ANALYZED AND PRESENTED IN A FORM SUITABLE FOR PREDICTING IMPACT OF MICROWAVE RADIATION ON PLANT ASSOCIATIONS IN FUTURE RECTENNA SITES AND FOR DEVELOPMENT OF STRATEGIES FOR MANAGEMENT OF VEGETATIONAL RESOURCES IN THESE SITES.
- INFORMATION TO BE DERIVED: ADEQUACY OF HEAT BALANCE THEORY AND MODELS TO PREDICT PLANT RESPONSE TO MICROWAVE RADIATION AND USEFULNESS OF EXPERIMENTAL AND THEORETICAL DATA TO DEVELOP MANAGEMENT STRATEGIES FOR FLORAL COMPONENTS OF RECTENNA SITES.
- EXPERIMENT TIME:

MONTHS TO COMPLETE	2
MAN YEARS	.3

- COST FOR RESEARCH: $10K
- NEW FACILITIES REQUIRED:

TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
NONE			

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TABLE 129

7.2 EFFECTS OF ACUTE MICROWAVE RADIATION ON SELECTED PLANTS

PROTOCOL 7.2 1.0 EXPERIMENTAL PLANT SELECTION

- o HYPOTHESIS OR TASK: SELECT EXPERIMENTAL PLANTS WITH POTENTIAL FOR YIELDING COMPARATIVE DATA ON MICROWAVE INDUCED THERMAL STRESS.
- o APPROACH: DETERMINE POTENTIAL TARGET SPECIES BY IDENTIFYING DOMINANT PLANT ASSOCIATIONS IN THE UNITED STATES. CLASSIFY SPECIES, WHICH MAY BE AMENABLE TO LABORATORY CULTIVATION, ON THE BASIS OF MAJOR MORPHOLOGICAL AND PHYSIOLOGICAL CHARACTERISTICS WHICH INFLUENCE THEIR RESPONSE TO THERMAL LOADING.
- o INFORMATION TO BE DERIVED: POTENTIAL TARGET SPECIES WILL BE IDENTIFIED. CLASSIFICATION ON THE BASIS OF THERMAL RESISTANCE WILL ALLOW SELECTION OF EXPERIMENTAL PLANTS WHICH EXHIBIT A SPECTRUM OF SENSITIVITIES TO THERMAL LOADING.
- o EXPERIMENT TIME:

MONTHS TO COMPLETE	3
MAN YEARS	.5

- o COST FOR RESEARCH: $14K
- o NEW FACILITIES REQUIRED:

TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
NONE			

TABLE 130

7.2 EFFECTS OF ACUTE MICROWAVE RADIATION ON SELECTED PLANTS

PROTOCOL 7.2.2.0 CULTIVATION OF EXPERIMENTAL PLANTS

- HYPOTHESIS OR TASK: DETERMINE CULTURE REQUIREMENTS OF CANDIDATE SPECIES AND THEIR SUITABILITY AS EXPERIMENTAL SUBJECTS FOR SMALL SCALE LABORATORY INVESTIGATIONS.
- APPROACH: SEEDS OF CANDIDATE SPECIES, WHEN POSSIBLE, WILL BE OBTAINED FROM SEED SUPPLY HOUSES, WHILE PLANTS NOT READILY PROPAGATED FROM SEEDS WILL BE PROCURED FROM NURSERIES. CULTURE REQUIREMENTS OF EACH SPECIES WILL BE DETERMINED BY LABORATORY EXPERIMENTATION, PERSONAL CONTACT WITH VEGETATION AND CROP SPECIALISTS, AND FROM DATA AVAILABLE IN THE LITERATURE. POTTING SOILS, NUTRIENT MEDIA, WATERING SCHEDULES, AND ENVIRONMENTAL PARAMETERS WILL BE VARIED TO DETETERMINE CONDITIONS OPTIMUM FOR GROWTH AND LIFE CYCLE COMPLETION.
- INFORMATION TO BE DERIVED: DETERMINATIONS OF AVAILABILITY AND CULTURE REQUIREMENTS OF CANDIDATE SPECIES WILL FACILITATE FINAL SELECTION OF EXPERIMENTAL PLANTS ON THE BASIS OF AVAILABILITY OF DEVELOPMENTAL STAGES, DURATION OF LIFE CYCLE, FACILITIES REQUIREMENTS, AND EASE OF CULTURE. THOSE SPECIES WHICH PRODUCE SUFFICIENT QUANTITIES OF EXPERIMENTAL MATERIAL WITHIN A REASONABLE TIME FRAME AND WITH MINIMUM MANIPULATION OF CULTURE PARAMETERS WILL BE IDENTIFIED.
- EXPERIMENT TIME:

MONTHS TO COMPLETE	4
MAN YEARS	.7

- COST FOR RESEARCH: $18K
- NEW FACILITIES REQUIRED:

	TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
7.2.2.1	ENVIRONMENTAL GROWTH CHAMBERS	$55K	0.2	3 MONTHS

TABLE 131

7.2 EFFECTS OF ACUTE MICROWAVE RADIATION ON SELECTED PLANTS

PROTOCOL 7.2.3.0 DOSIMETRY

- o HYPOTHESIS OR TASK: ESTABLISH METHODOLOGY FOR EXPOSING PLANTS TO MICROWAVE RADIATION AND MEASURING ABSORBED ENERGY.
- o APPROACH: INCIDENT MICROWAVE RADIATION WILL BE MEASURED WITH A BROADBAND ELECTROMAGNETIC RADIATION HAZARD METER. SEVERAL METHODS (COOLING-CURVE TECHNIQUE, THERMISTORS, ENERGY ABSORBED BY EQUIVALENT WATER LOAD, ABSORPTION COEFFICIENT DETERMINED BY USE OF MICROWAVE DETECTOR) WILL BE EVALUATED FOR MEASURING ABSORBED ENERGY AT THE PROPOSED SPS FREQUENCY OF 2450 MHz.
- o INFORMATION TO BE DERIVED: THE MOST RELIABLE METHOD FOR MEASURING ABSORBED ENERGY WITH MINIMUM INTERFERENCE WITH ENERGY FIELDS WILL BE IDENTIFIED.
- o EXPERIMENT TIME:

MONTHS TO COMPLETE	5
MAN YEARS	.8

- o COST FOR RESEARCH: $17K
- o NEW FACILITIES REQUIRED:

	TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
COMMON WITH 7.2.2.0				
7.2.3.1	MICROWAVE SOURCES	$17K	0.2	5 MONTHS
7.2.3.2	TEMPERATURE MONITORING SYSTEMS	$10K	0.2	5 MONTHS

TABLE 132

7.2 EFFECTS OF ACUTE MICROWAVE RADIATION ON SELECTED PLANTS

PROTOCOL 7.2.4.0 DOSE RESPONSE RELATIONSHIPS

- o HYPOTHESIS OR TASK: DETERMINE ACUTE LEVELS OF MICROWAVE RADIATION FOR DEVELOPMENTAL STAGES OF EXPERIMENTAL PLANTS AND EFFECTS OF ENVIRONMENTAL CONDITIONS ON SENSITIVITY.
- o APPROACH: DEVELOPMENTAL STAGES OF SELECTED PLANTS WILL BE EXPOSED TO INCREASING POWER DENSITIES AT THE PROPOSED SPS FREQUENCY OF 2450 MHz. EFFECTS OF MICROWAVES ON GERMINATION, VEGETATIVE GROWTH, AND REPRODUCTIVE CAPABILITIES WILL BE RECORDED AT EACH EXPOSURE LEVEL UNDER VARIOUS CONDITIONS OF RADIANT ENERGY, PHOTOPERIOD, TEMPERATURE, AND SOIL MOISTURE.
- o INFORMATION TO BE DERIVED: DOSE-RESPONSE CURVES WILL INDICATE MICROWAVE POWER DENSITIES LETHAL TO EXPERIMENTAL PLANTS AND PLANT SYMPTOMATOLOGY ASSOCIATED WITH VARIOUS DEGREES OF ACUTE EXPOSURE.
- o EXPERIMENT TIME:

MONTHS TO COMPLETE	12
MAN YEARS	2

- o COST FOR RESEARCH: $51K
- o NEW FACILITIES REQUIRED:

TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
COMMON WITH 7.2.2.0 AND 7.2.3.0			

TABLE 133

7.2 EFFECTS OF ACUTE MICROWAVE RADIATION ON SELECTED PLANTS

PROTOCOL 7.2.5.0 BIOCHEMICAL AND PHYSIOLOGICAL RESPONSES

- HYPOTHESIS OR TASK: DETERMINE BIOCHEMICAL AND PHYSIOLOGICAL FACTORS ASSOCIATED WITH PLANT RESPONSE AND SUSCEPTIBILITY TO MICROWAVE RADIATION.
- APPROACH: BIOCHEMICAL (TOTAL PROTEIN, TOTAL LIPIDS, TOTAL CARBOHYDRATES, NUCLEIC ACIDS, FATTY ACIDS, STARCHES, SUGARS, CHLOROPHYLL CONTENT) AND PHYSIOLOGICAL (PHOTOSYNTHETIC, RESPIRATORY AND TRANSPIRATION RATES) CHARACTERISTICS WILL BE COMPARED TO THOSE OF CONTROL PLANTS. ABSORBED ENERGY LEVELS AND TEMPERATURE CHANGES WILL BE RECORDED AND CORRELATED WITH THE ABOVE PARAMETERS.
- INFORMATION TO BE DERIVED: BIOCHEMICAL AND PHYSIOLOGICAL FACTORS ASSOCIATED WITH PLANT RESPONSE AND/OR SUSCEPTIBILITY TO MICROWAVES WILL BE IDENTIFIED.
- EXPERIMENT TIME:

MONTHS TO COMPLETE	6
MAN YEARS	1

- COST FOR RESEARCH: $20K
- NEW FACILITIES REQUIRED:

TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
COMMON WITH 7.2.2.0 AND 7.2.3.0			

TABLE 134

7.2 EFFECTS OF ACUTE MICROWAVE RADIATION ON SELECTED PLANTS

PROTOCOL 7.2.6.0 MULTIPLE PLANT EXPOSURES

- HYPOTHESIS OR TASK: DETERMINE LEVELS AND DISTRIBUTION OF ENERGY ASSOCIATED WITH SIMULTANEOUS EXPOSURE OF PURE AND MIXED POPULATIONS OF PLANTS TO MICROWAVE RADIATION.
- APPROACH: COMPARISONS OF ENERGY LEVELS (INCIDENT AND ABSORBED) AT HIGH POPULATION DENSITIES WITH FREE SPACE LEVELS WILL BE MADE.
- INFORMATION TO BE DERIVED: EFFECTS OF POPULATION DENSITY ON ENERGY DISTRIBUTION AND RESULTANT PLANT RESPONSE.
- EXPERIMENT TIME:

MONTHS TO COMPLETE	4
MAN YEARS	.6

- COST OF RESEARCH: $14K
- NEW FACILITIES REQUIRED:

TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
COMMON WITH 7.2.2.0 AND 7.2.3.0			

TABLE 135

7.2 EFFECTS OF ACUTE MICROWAVE RADIATION ON SELECTED PLANTS

PROTOCOL 7.2.7.0 FINAL REPORT

- o HYPOTHESIS OR TASK: COMPILE DATA AND PREPARE FINAL REPORT ON THREE YEAR RESEARCH EFFORT.
- o APPROACH: ANALYZE DATA FOR USE IN PREDICTING PLANT RESPONSE TO MICROWAVE RADIATION AND MANAGEMENT OF PLANT COMMUNITIES SURROUNDING RECTENNA SITES.
- o INFORMATION TO BE DERIVED: ADEQUACY OF USING KNOWN PLANT CHARACTERISTICS TO PREDICT PLANT RESPONSE TO MICROWAVE RADIATION AND POSSIBLE IMPACT OF MICROWAVE RADIATION ON PLANT COMMUNITIES ASSOCIATED WITH RECTENNA SITES.
- o EXPERIMENT TIME:

MONTHS TO COMPLETE	2
MAN YEARS	.3

- o COST FOR RESEARCH: $10K
- o NEW FACILITIES REQUIRED:

TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
NONE			

TABLE 136

7.3 EFFECTS OF CHRONIC, LOW-LEVEL MICROWAVE RADIATION ON SELECTED PLANTS

PROTOCOL 7.3.1.0 EXPERIMENTAL PLANT SELECTION

- o HYPOTHESIS OR TASK: SELECT EXPERIMENTAL PLANTS WITH POTENTIAL FOR YIELDING COMPARATIVE DATA ON PLANT RESPONSE TO THERMAL CHANGES INDUCED BY CHRONIC EXPOSURE TO MICROWAVE RADIATION.
- o APPROACH: DETERMINE POTENTIAL TARGET SPECIES BY IDENTIFYING DOMINANT AGRICULTURAL AND NATURAL PLANT ASSOCIATIONS IN THE UNITED STATES. CLASSIFY SPECIES, WHICH MAY BE AMENABLE TO LABORATORY CULTIVATION, ON THE BASIS OF MAJOR MORPHO-PHYSIOLOGICAL CHARACTERISTICS WHICH INFLUENCE RESPONSE TO THERMAL LOADING. DEVELOP VARIOUS SCENARIOS WHICH WILL PROVIDE COMPARATIVE DATA ON PLANT RESPONSES TO CONTINUOUS MICROWAVE RADIATION.
- o INFORMATION TO BE DERIVED: POTENTIAL TARGET SPECIES WILL BE IDENTIFIED. EXPERIMENTAL PLANTS WILL BE SELECTED WHICH EXHIBIT A SPECTRUM OF SENSITIVITIES TO THERMAL LOADING.
- o EXPERIMENT TIME:

MONTHS TO COMPLETE	4
MAN YEARS	.6

- o COST FOR RESEARCH: $17K
- o NEW FACILITIES REQUIRED:

TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
NONE			

TABLE 137

7.3 EFFECT OF CHRONIC, LOW-LEVEL MICROWAVE RADIATION ON SELECTED PLANTS

PROTOCOL 7.3.2.0 CULTIVATION OF EXPERIMENTAL PLANTS

- <u>HYPOTHESIS OR TASK</u>: DETERMINE CULTURE REQUIREMENTS AND GROWTH CHARACTERISTICS OF CANDIDATE SPECIES UNDER BIOTRON CONDITIONS.
- <u>APPROACH</u>: CULTURE REQUIREMENTS OF EACH CANDIDATE SPECIES WILL BE DETERMINED BY EXPERIMENTATION BASED ON DATA AVAILABLE IN THE LITERATURE AND PERSONAL CONTACT WITH VEGETATION AND CROP SPECIALISTS. POTTING SOILS, NUTRIENT MEDIA, WATERING SCHEDULES, AND ENVIRONMENTAL PARAMETERS WILL BE VARIED TO DETERMINE CONDITIONS OPTIMUM FOR GROWTH AND LIFE CYCLE COMPLETION. GROWTH RATES, STEM HEIGHT, LEAF SIZE, AND DURATION OF LIFE CYCLE WILL BE DETERMINED FOR EACH SPECIES. THESE PARAMETERS WILL BE USED TO SELECT EXPERIMENTAL PLANTS WITH CHARACTERISTICS SUITABLE FOR EXPOSURE TO CHRONIC, LOW-LEVEL MICROWAVE RADIATION.
- <u>INFORMATION TO BE DERIVED</u>: CULTURE REQUIREMENTS OF CANDIDATE SPECIES AND THEIR SUITABILITY AS EXPERIMENTAL SUBJECTS FOR CHRONIC EXPOSURE TO MICROWAVE RADIATION IN BOTH UNI- AND MULTISPECIES SCENARIOS.
- <u>EXPERIMENT TIME</u>:

MONTHS TO COMPLETE	4
MAN YEARS	.6

- <u>COST FOR RESEARCH</u>: $16K
- <u>NEW FACILITIES REQUIRED</u>:

	TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
7.3.2.1	BIOTRON MODIFICATION AND RENTAL	$79K	0.3	4 MONTHS

7.3 EFFECTS OF CHRONIC, LOW-LEVEL MICROWAVE RADIATION ON SELECTED PLANTS

PROTOCOL 7.3.3.0 DOSIMETRY

- HYPOTHESIS OR TASK: ESTABLISH METHODOLOGY FOR MEASURING ABSORBED ENERGY BY PLANTS CHRONICALLY EXPOSED TO MICROWAVE RADIATION.
- APPROACH: INCIDENT MICROWAVE RADIATION WILL BE MEASURED WITH A BROADBAND ELECTROMAGNETIC RADIATION HAZARD METER. SEVERAL METHODS (THERMISTORS, ENERGY ABSORBED BY EQUIVALENT WATER LOAD, ABSORPTION COEFFICIENT DETERMINED BY USE OF MICROWAVE DETECTOR) WILL BE EVALUATED FOR USE IN CORRELATING INCIDENT AND ABSORBED ENERGY FOR SPECIES EXPOSED SINGLY AND IN COMBINATIONS WITH OTHER SPECIES. A SYSTEM FOR CONTINUOUS MONITORING OF INCIDENT MICROWAVE RADIATION WILL BE ESTABLISHED.
- INFORMATION TO BE DERIVED: THE MOST RELIABLE METHOD FOR MEASURING ABSORBED ENERGY AND TEMPERATURE CHANGES IN PLANTS EXPOSED TO CHRONIC, LOW-LEVEL MICROWAVE RADIATION.
- EXPERIMENT TIME:

MONTHS TO COMPLETE	4
MAN YEARS	.6

- COST FOR RESEARCH: $14K
- NEW FACILITIES REQUIRED:

	TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
COMMON WITH 7.3.2.0				
7.3.3.1	POWER SOURCES	$54K	0.3	7 MONTHS
7.3.3.2	MICROWAVE AND TEMPERATURE MONITORING SYSTEMS	$18K	0.3	5 MONTHS

TABLE 139

7.3 EFFECTS OF CHRONIC, LOW-LEVEL MICROWAVE RADIATION ON SELECTED PLANTS

PROTOCOL 7.3.4.0 PLANT GROWTH RESPONSES

- <u>HYPOTHESIS OR TASK</u>: DETERMINE PLANT SYMPTOMATOLOGY AND SENSITIVITY ASSOCIATED WITH LONG-TERM EXPOSURE TO LOW LEVELS OF MICROWAVE RADIATION.
- <u>APPROACH</u>: SMALL SCALE SCENARIOS CONSISTING OF VARIOUS SPECIES AND ENVIRONMENTAL CONDITIONS WILL BE EXPOSED TO CHRONIC MICROWAVE RADIATION AT THE FREQUENCY (2450 MHz) AND MAXIMUM POWER DENSITY (10 mW/cm^2) SPECIFIED BY THE SPS. GROWTH CHARACTERISTICS, SEED GERMINATION, FRUIT SET, AND SEED VIABILITY WILL BE MEASURED AND COMPARED TO CONTROL PLANTS WHICH DO NOT RECEIVE MICROWAVE RADIATION. SPECIES WITH RELATIVELY SHORT LIFE CYCLE WILL BE SUBJECTED TO CHRONIC EXPOSURE OVER AT LEAST TWO GENERATIONS.
- <u>INFORMATION TO BE DERIVED</u>: ABILITY OF PLANTS TO GROW AND REPRODUCE UNDER CHRONIC EXPOSURE TO MAXIMUM POWER DENSITIES EXPECTED TO OCCUR IN RECTENNA SITES. RELATIVE SENSITIVITIES OF DEVELOPMENTAL STAGES OF VARIOUS SPECIES WILL ALSO BE IDENTIFIED.
- <u>EXPERIMENT TIME</u>:

MONTHS TO COMPLETE	12
MAN YEARS	2

- <u>COST FOR RESEARCH</u>: $50K
- <u>NEW FACILITIES REQUIRED</u>:

TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
COMMON WITH 7.3.2.0 AND 7.3.3.0			

7.3 EFFECTS OF CHRONIC, LOW-LEVEL MICROWAVE RADIATION ON SELECTED PLANTS

PROTOCOL 7.3.5.0 BIOCHEMICAL AND PHYSIOLOGICAL RESPONSES

- HYPOTHESIS OR TASK: DETERMINE BIOCHEMICAL AND PHYSIOLOGICAL RESPONSES ASSOCIATED WITH EXPOSURE TO CHRONIC, LOW-LEVEL MICROWAVE RADIATION.
- APPROACH: SELECTED BIOCHEMICAL (TOTAL PROTEIN, TOTAL LIPIDS, TOTAL CARBOHYDRATES, NUCLEIC ACIDS, FATTY ACIDS, STARCHES, SUGARS, CHLOROPHYLL CONTENT) AND PHYSIOLOGICAL (PHOTOSYNTHETIC, RESPIRATORY, AND TRANSPIRATION RATES) PARAMETERS WILL BE MEASURED FOR SPECIES WITH RELATIVELY HIGH AND LOW SENSITIVITIES TO LOW-LEVELS OF MICROWAVE RADIATION. ABSORBED ENERGY LEVELS AND THERMAL CHANGES BY EACH SPECIES WILL BE CORRELATED WITH EACH OF THE ABOVE PARAMETERS. CONTROL GROUPS WILL ALSO BE UTILIZED FOR EACH SPECIES INVESTIGATED.
- INFORMATION TO BE DERIVED: BIOCHEMICAL AND PHYSIOLOGICAL FACTORS ASSOCIATED WITH PLANT SUSCEPTIBILITY TO CHRONIC, LOW-LEVEL MICROWAVE RADIATION.
- EXPERIMENT TIME:

MONTHS TO COMPLETE	9
MAN YEARS	1.5

- COST FOR RESEARCH: $36K
- NEW FACILITIES REQUIRED:

TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
COMMON WITH 7.3.2.0 AND 7.3.3.0			

TABLE 141

7.3 EFFECTS OF CHRONIC, LOW-LEVEL MICROWAVE RADIATION ON SELECTED PLANTS

PROTOCOL 7.3.6.0 FINAL REPORT

- HYPOTHESIS OR TASK: COMPILE DATA AND PREPARE FINAL REPORT ON THREE YEAR RESEARCH EFFORT.
- APPROACH: ANALYZE DATA FOR USE IN PREDICTING PLANT RESPONSE TO CHRONIC, LOW-LEVEL MICROWAVE RADIATION AND MANAGEMENT OF PLANT COMMUNITIES SURROUNDING RECTENNA SITES.
- INFORMATION TO BE DERIVED: ADEQUACY OF USING KNOWN PLANT CHARACTERISTICS TO PREDICT PLANT RESPONSE TO MICROWAVE RADIATION AND POSSIBLE IMPACT ON PLANT COMMUNITIES ASSOCIATED WITH RECTENNA SITES.
- EXPERIMENT TIME:

MONTHS TO COMPLETE	3
MAN YEARS	.5

- COST FOR RESEARCH: $14K
- NEW FACILITIES REQUIRED:

TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
NONE			

7.4 NON-THERMAL EFFECTS OF MICROWAVE RADIATION ON PLANTS

PROTOCOL 7.4.1.0 EXPERIMENTAL PLANT SELECTION

- o HYPOTHESIS OR TASK: SELECT SPECIES SUITABLE FOR INVESTIGATING NON-THERMAL EFFECTS OF MICROWAVE RADIATION ON PLANTS.
- o APPROACH: EXPERIMENTAL PLANTS WILL BE SELECTED FROM THOSE SPECIES COMMONLY USED IN INVESTIGATING PLANT PHYSIOLOGICAL AND BIOCHEMICAL PROCESSES. EASE OF CULTIVATION, RELATIVE SIZE AT MATURITY, AND DURATION OF LIFE CYCLE WILL SERVE AS BASIC CRITERIA FOR PLANT SELECTION.
- o INFORMATION TO BE DERIVED: PLANT SPECIES SUITABLE FOR COMPARATIVE INVESTIGATIONS OF GROWTH AND PHYSIOLOGICAL RESPONSES TO EQUIVALENT THERMAL LOADS PRODUCED BY CONVENTIONAL HEATING AND LOW-LEVEL MICROWAVE RADIATION.
- o EXPERIMENT TIME:

MONTHS TO COMPLETE	2
MAN YEARS	.3

- o COST FOR RESEARCH: $10K
- o NEW FACILITIES REQUIRED:

TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
NONE			

TABLE 143

7.4 NON-THERMAL EFFECTS OF MICROWAVE RADIATION ON PLANTS

PROTOCOL 7.4.2.0 CULTIVATION OF EXPERIMENTAL PLANTS

- o HYPOTHESIS OR TASK: ESTABLISH CULTURE PROGRAM WHICH WILL PROVIDE A RELIABLE SUPPLY OF EXPERIMENTAL PLANTS SUITABLE FOR USE IN THIS PROGRAM.
- o APPROACH: CULTURE REGIMES WILL BE ESTABLISHED BY DETERMINING POTTING SOILS, NUTRIENT MEDIA, WATERING SCHEDULES, AND ENVIRONMENTAL PARAMETERS NECESSARY FOR OPTIMUM GROWTH OF EACH SPECIES. PLANTING SCHEDULES WILL BE ESTABLISHED TO PROVIDE A READY SUPPLY OF EXPERIMENTAL PLANTS OF UNIFORM AGE AND SIZE.
- o INFORMATION TO BE DERIVED: CULTURE REGIMES NECESSARY FOR PROVIDING NON-STRESSED PLANTS OF UNIFORM QUALITY IN QUANTITIES SUFFICIENT FOR THE EXPERIMENTAL PROGRAM.
- o EXPERIMENT TIME:

MONTHS TO COMPLETE	4
MAN YEARS	.6

- o COST FOR RESEARCH: $16K
- o NEW FACILITIES REQUIRED:

	TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
7.4.2.1	CULTURE FACILITIES	$44K	0.3	2 MONTHS

TABLE 144

7.4 NON-THERMAL EFFECTS OF MICROWAVE RADIATION ON PLANTS

PROTOCOL 7.4.3.0 DOSIMETRY

- o HYPOTHESIS OR TASK: ESTABLISH METHODOLOGY FOR MEASURING HEAT LOADS IN PLANTS.
- o APPROACH: VARIOUS METHODS (THERMISTORS, EXTERNAL TEMPERATURE MONITORS, COOLING-CURVES, ETC.) WILL BE EVALUATED FOR USE IN DETERMINING THERMAL CHANGES IN PLANTS PRODUCED BY CONVENTIONAL MEANS AND LOW-LEVEL MICROWAVE RADIATION. INCIDENT MICROWAVE RADIATION WILL BE MEASURED WITH A BROADBAND ELECTROMAGNETIC HAZARD METER.
- o INFORMATION TO BE DERIVED: THE MOST RELIABLE AND ACCURATE METHOD FOR DETERMINING TEMPERATURE RESPONSES OF PLANTS TO CONVENTIONAL HEATING AND LOW-LEVEL MICROWAVE RADIATION.
- o EXPERIMENT TIME:

MONTHS TO COMPLETE	6
MAN YEARS	1

- o COST FOR RESEARCH: $23K
- o NEW FACILITIES REQUIRED:

	TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
COMMON WITH 7.4.2.0				
7.4.3.1	MICROWAVE SOURCES	$14K	0.3	6 MONTHS
7.4.3.2	MICROWAVE AND TEMPERATURE MONITORING SYSTEMS	$11K	0.3	6 MONTHS

TABLE 145

7.4 NON-THERMAL EFFECTS OF MICROWAVE RADIATION ON PLANTS

PROTOCOL 7.4.4.0 GROWTH RESPONSES TO EQUIVALENT CONVENTIONAL AND MICROWAVE HEAT LOADS

- HYPOTHESIS OR TASK: COMPARE GROWTH RESPONSES OF PLANTS AT EQUIVALENT HEAT LOADS PRODUCED BY CONVENTIONAL MEANS AND MICROWAVE RADIATION.
- APPROACH: EXPERIMENTAL PLANTS WILL BE EXPOSED TO MICROWAVE RADIATION (2450 MHz; <10 mW/cm^2) AND EQUILIBRIUM HEAT LOADS WILL BE DETERMINED. OTHER PLANTS OF SIMILAR AGE AND SIZE WILL BE EXPOSED TO SIMILAR EQUILIBRIUM HEAT LOADS BY USE OF CONVENTIONAL METHODS OF INCREASING PLANT TEMPERATURE. GROWTH RATES (CHANGES IN DRY WEIGHT AND STEM LENGTH) AND GROWTH CHARACTERISTICS (LEAF SIZE, DURATION OF LIFE CYCLE, % GERMINATION, FRUIT SET, CHLOROPHYLL CONTENT) WILL BE DETERMINED FOR EACH GROUP.
- INFORMATION TO BE DERIVED: DATA FOR IDENTIFYING POSSIBLE NON-THERMAL EFFECTS OF MICROWAVES ON SELECTED GROWTH CHARACTERISTICS OF PLANTS.
- EXPERIMENT TIME:

MONTHS TO COMPLETE	12
MAN YEARS	2

- COST FOR RESEARCH: $50K
- NEW FACILITIES REQUIRED:

TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
COMMON WITH 7.4.2.0 AND 7.4.3.0			

7.4 NON-THERMAL EFFECTS OF MICROWAVE RADIATION ON PLANTS

PROTOCOL 7.4.5.0 PHYSIOLOGICAL RESPONSES TO EQUIVALENT CONVENTIONAL AND MICROWAVE HEAT LOADS

- HYPOTHESIS OR TASK: COMPARE PHYSIOLOGICAL RESPONSES OF PLANTS AT EQUIVALENT TEMPERATURE EQUILIBRIA UNDER CONVENTIONAL HEATING AND LOW-LEVEL MICROWAVE RADIATION.
- APPROACH: PLANTS WILL BE HEATED TO SIMILAR TEMPERATURE LEVELS BY CONVENTIONAL MEANS AND LOW-LEVEL MICROWAVE RADIATION (2450 MHz; <10 mW/cm^2). ONCE TEMPERATURE EQUILIBRIA ARE ACHIEVED IN EACH GROUP, DIFFERENCES IN SELECTED PHYSIOLOGICAL PARAMETERS (TRANSPIRATION, PHOTOSYNTHESIS, RESPIRATION) BETWEEN THE TWO GROUPS WILL BE DETERMINED.
- INFORMATION TO BE DERIVED: DATA FOR IDENTIFYING POSSIBLE NON-THERMAL EFFECTS OF MICROWAVES ON SELECTED PHYSIOLOGICAL PROCESSES IN PLANTS.
- EXPERIMENT TIME:

MONTHS TO COMPLETE	10
MAN YEARS	1.6

- COST FOR RESEARCH: $37K
- NEW FACILITIES REQUIRED:

TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
COMMON WITH 7.4.2.0 AND 7.4.3.0			

TABLE 147

7.4 NON-THERMAL EFFECTS OF MICROWAVE RADIATION ON PLANTS

PROTOCOL 7.4.6.0 FINAL REPORT

- HYPOTHESIS OR TASK: COMPILE DATA AND PREPARE FINAL REPORT ON THREE YEAR EFFORT.
- APPROACH: ANALYZE DATA FOR IDENTIFICATION OF NON-THERMAL EFFECTS OF MICROWAVES ON PLANT GROWTH CHARACTERISTICS AND PHYSIOLOGICAL PROCESSES. WRITE A FINAL REPORT WHICH PRESENTS RESULTS FROM THE THREE YEAR EFFORT.
- INFORMATION TO BE DERIVED: THE EXISTENCE OF NON-THERMAL MICROWAVE EFFECTS ON PLANT GROWTH AND/OR PHYSIOLOGY.
- EXPERIMENT TIME:

MONTHS TO COMPLETE	2
MAN YEARS	.6

- COST FOR RESEARCH: $16K
- NEW FACILITIES REQUIRED:

TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
NONE			

MILESTONE AND FUNDING SUMMARY

TABLE 148

MILESTONE AND FUNDING SUMMARY

	PHASE A YEAR	COST $K		
	0 1 2 3	Exper.	Facil.	Question
7.1.0.0 Use of Heat Balance Theory to Predict Thermal Responses of Plants to Microwave Radiation	∇	--	---	168
7.1.1.0 Model Development	∇	48	---	
7.1.2.0 Selection of Model Plant Associations	∇	24	---	
7.1.3.0 Application of Model	∇	49	---	
7.1.4.0 Model Testing and Refinement	∇	14	---	
7.1.5.0 Predictions	∇	23	---	
7.1.6.0 Analysis and Report	∇	10	---	
7.2.0.0 Effects of Acute Microwave Radiation on Selected Plants	∇	--	---	226
7.2.1.0 Experimental Plant Selection	∇	14	---	
7.2.2.0 Cultivation of Experimental Plants	∇	18	55	

TABLE 148. - Continued

	PHASE A YEAR	COST $K		
	0 1 2 3	Exper.	Facil.	Question
7.2.3.0 Dosimetry	▽	17	27	
7.2.4.0 Dose Response Relationships.	▽	51	---	
7.2.5.0 Biochemical and Physiological Responses	▽	20	---	
7.2.6.0 Multiple Plant Exposures	▽	14	---	
7.2.7.0 Analysis and Report.	▽	10	---	
7.3.0.0 Effects of Chronic, Low-Level Microwave Radiation on Selected Plants	▽	--	---	299
7.3.1.0 Experimental Plant Selection	▽	17	---	
7.3.2.0 Cultivation of Experimental Plants	▽	16	79	
7.3.3.0 Dosimetry	▽	14	72	
7.3.4.0 Plant Growth Responses	▽	50	---	
7.3.5.0 Biochemical and Physiological Responses	▽	36	---	
7.3.6.0 Analysis and Report.	▽	14	---	

TABLE 148. - Concluded

	PHASE A YEAR 0 1 2 3	COST $K Exper.	Facil.	Question
7.4.0.0 Non-Thermal Effects of Microwave Radiation on Plants	∇	--	---	221
7.4.1.0 Experimental Plant Selection	∇	10	---	
7.4.2.0 Cultivation of Experimental Plants	∇	16	44	
7.4.3.0 Dosimetry	∇	23	25	
7.4.4.0 Growth Responses to Equivalent Conventional and Microwave Heat Loads	∇	50	---	
7.4.5.0 Physiological Responses to Equivalent Conventional and Microwave Heat Loads	∇	37	---	
7.4.6.0 Analysis and Report	∇	16	---	

PILOT EXPERIMENTATION

Experiment 1. Microwave Source. -

Assumption: (Diathermy microwave generator is suitable for acute and chronic tests.)

Results of Testing: A Burdick mW/200 diathermy machine was evaluated as a possible microwave source. The maximum power output (200 mW/cm^2) is more than sufficient for chronic testing, but is inadequate for conducting acute tests within a reasonable time frame. Fluctuations in power density ($\pm$ 10 mW/cm^2) were noted by use of a broadband electro-magnetic hazard meter (RAHAM, Model 1), thus power output from this instrument is not uniform. Localized areas of relatively high power densities (hot spots) were also noted in the energy field.

Experiment 2. Energy Absorption.-

Assumption: (Electro-magnetic hazard meter can be utilized to determine energy absorption coefficient).

Results of Testing: The microwave power from a Burdick mW/200 diathermy machine was measured with a broadband electro-magnetic hazard meter (RAHAM, Model 1). Dry seeds of *Phaseolus vulgaris*, *Pisum sativa*, and *Zea mayes* were placed between the microwave source and detector. No noticeable change was noted in the probe reading. Soaking the seeds for 24 hours had no effect on energy absorption. However, leaves of these plants and seed pods of *Phaseolus vulgaris* absorbed and/or reflected approximately 10% of the incident energy.

Experiment 3. Dose-Response of Seeds. -

Assumption: (Short-term exposure of seeds to microwave energy inhibits germination).

Results of Testing: Dry seeds of *Phaseolus vulgaris* and *Pisum sativum* were exposed for 10, 30, 60, and 120 minutes to 200 mW/cm^2 of microwave energy from a Burdick mW/200 diathermy machine. After exposure, the exposed seeds and controls were placed in a moist chamber and allowed to germinate. If, at the end of three days, the seed produced a radicle at least 3 mm in length, it was considered as having germinated.

These studies indicated no effect of the above exposure levels on seed germination. Soaking the seeds for 24 hours prior to exposure did not increase their sensitivity to microwave illumination at the exposure levels utilized in these studies.

Experiment 4. Plant Response to Microwave Illumination. -

Assumption: (External symptoms are apparent after short-term exposure to microwaves).

Results of Testing: Ten day plants of *Phaseolus vulgaris* were exposed for sixty minutes to 200 mW/cm^2 of microwave energy from a Burdick mW/200 diathermy machine. Gross external appearances of these plants were not noticeably different from the control group after an additional seven days growth in a controlled environment culture chamber.

X. DOSIMETRY AND FACILITY REQUIREMENTS*

SIGNIFICANCE OF CATEGORY

Dosimetry R & D Requirements.- A key aspect in performing and evaluating research on the biological and ecological effects of SPS microwave illumination is to establish, among the participants and sponsors of such research, a common basis for defining microwave energy absorption terminology, and to develop appropriate methods and instrumentation for determining dose rates, i.e., "Specific Absorption Rates" (SARs), and internal spatial distributions of SAR in animal and plant species likely to be subjected to microwaves at representative SPS receiver sites. Without such commonality and methodology, it would be difficult to coordinate the bioeffects research programs to be implemented under SPS funding, assess the significance of research findings on any specific species of interest, relative to anticipated levels of microwave fields at such sites, or to interrelate the results obtained in the various programs.

In general, the subject of microwave dosimetry in biological entities is exceedingly complex, because the internal distribution of SAR in any species is dependent on the electromagnetic properties of its constituents and their internal arrangement, as well as on the characteristics of the microwave field. Rapid progress is being made on the development of dosimetry concepts, techniques, and devices for use in conducting bioeffects research on laboratory animal species, such as rats, mice, and non-human primates, and aspects of this dosimetry methodology are undoubtedly applicable for use on some species of fauna and flora of potential importance, relative to the SPS. However, SPS funding will be needed to implement adaptation of such techniques. In addition, SPS funding will be required for developing adequate dosimetry methodology for other species of SPS significance. In the context of the time frame to the decision point on SPS implementation, it is essential to appraise the state of the art in microwave dosimetry, relative to the needs of the SPS bioeffects programs to be pursued, and to support specific dosimetry developments that

*From Final Report for Ames Research Center, NASA Contract NAS2-9546, "Research Program Definition for the Study of the Biological and Ecological Effects of Energy Transmission by Microwaves - Dosimetry Concept Development and Future Facility Requirements", D. C. L. Jones, P. Polson, L. Heynick and B. Holt, SRI International, Menlo Park, CA., January, 1978

are essential toward realizing meaningful results from these bioeffects programs.

Accordingly, the objective of the dosimetry research area is to ascertain the SPS related requirements for R & D in dosimetry, and to formulate these requirements in terms of specific, prioritized program-element recommendations for implementation. A dual-path approach is proposed: 1) A Dosimetry and Electromagnetic Field Workshop supported with SPS funding will be held as soon as can be arranged; 2) A concurrent survey and analysis of the extant R & D on dosimetry will be performed under other sponsorship. The information derived from both of these paths will then be used to formulate the specific program-element recommendations.

Phase A Facilities. - The integrated experimental program must provide means for ensuring that results of exposures of test subjects may be interpreted in a manner that is relevant to the likely SPS situation. This can best be achieved by accurate knowledge of the exposure conditions existing at each laboratory and of the internal distributions of specific absorption rates (SARs) existing within the exposed subjects.

The task proposed here is an advanced support service rather than a research task per se. It is anticipated that several of the laboratories chosen to conduct research in Phase A will require assistance in designing, acquiring, constructing, and calibrating a suitable microwave exposure facility. One aspect of this task is to provide such assistance. Another aspect is the integration and validation of the approaches to microwave exposures across all laboratories, to ensure that appropriate sources (e.g., CW, instead of pulsed or modulated) are employed. A third aspect is the exact calibration of exposure fields and SARs, with calibration ultimately traceable to the National Bureau of Standards. The present state of the art is such that commercially available probes are used to measure exposure fields in the absence of a subject in the exposure field. These omnidirectional probes generally are stated to have a calibration accuracy of the order of ± dB. This means that a 20 mW/cm^2 field may be read as 16 mWcm^2 on one probe and as 25 mW/cm^2 on another. Calibration of fields with greater precision is a necessary task. Although desirable in principle, it does not appear feasible to specify one standard microwave illumination facility design for Phase A. The wide variety of biological areas proposed for investigation preclude any single approach. Some questions, such as chronic exposure of small mammals are best investigated in a cost-effective manner using facilities that have already

been developed in ongoing microwave research projects, and relating effects to within-tissue SAR values. The present state of the art for defining SAR involves infrared thermographic measurements on specially prepared carcasses and phantoms, and the use of nonperturbing temperature sensors on live animals. The thermographic technique is not a commercially available one, and is relatively expensive. A set of equipment common to all SPS related research, that can be taken to the separate laboratories in conjunction with the field calibration tasks, will provide a means for calibrating SARs in a reliable and uniform manner.

Phase B Facility Planning. - Phase A is designed to provide answers to key problems in the biological and ecological effects area. These answers will serve as partial input to DOE and NASA at the end of Phase A, when a decision is planned as to whether further commitment will be made to the SPS concept or not.

The present task, that of planning towards a Phase B facility, does not imply any commitment to continuation of the SPS program into Phase B. It is considered a necessary and important task in the present effort for two reasons: 1) The B facility is a long lead time item; 2) The cost of implementation of such a facility and the time required to bring it into operation are important inputs to the decision-making process for further commitment into Phase B. The task involves the orderly process of developing the plans for an Ecosystem Balance Facility (EBF) in a form suitable for incorporation into a Request for Proposals or an Invitation for Bids. The EBF is intended to provide the capability of illuminating a large area (e.g., 10^4 square meters or more) with microwave illumination to simulate conditions that will exist at the receiving antenna site and its environs. Within the illuminated area, it will be possible to irradiate whole ecosystems for periods of many years continuously, and to attempt to see what effects, if any, are caused by such exposure.

There appears to be many possible approaches to the facility design. This task will endeavor to choose among them and to come up with justifications as to why certain approaches are to be preferred, followed by elaboration of those approaches into reasonably detailed design and operational criteria.

Microcosm Experiments. - Some information concerning the effects of microwaves on ecosystems would appear to be necessary in deciding how best to approach the design of the Ecosystem

Balance Facility. Such information appears to be nonexistent at present, and so this task and the following one are designed to provide some preliminary data (primarily qualitative rather than quantitative) along these lines.

1. Microwave Interactions. - The interaction of microwave effects on soils, air, and organisms may initiate impacts that are not readily predicted from studies of these components in isolation. The probability of large effects of this sort is likely to be small, and the appropriate experimental approach uncertain. However, upper limits on time and costs are set by the need to move rapidly into the large-scale field experiments simulating SPS operations.

   This task is to determine whether conspicuous interactions exist among effects of microwave illumination on air, soil, vegetation, and animals. It is to be an aid in designing long-term experiments, and hence, should be brief and low in cost.

2. Species Diversity and Composition. - Whereas the previous experiment was designed to provide qualitative information about several systems parameters, the present experiment should provide both qualitative and quantitative data on only species diversity and composition for various levels of microwave illumination. The number of species per unit area and the relative abundance of species within biological communities are generally more sensitive indicators of stress than are changes in the productivity of those communities. Resistant species tend to utilize the resources normally used by the more sensitive species, thereby stabilizing productivity. Moreover, the presence of biological competitors can enhance the sensitivity of organisms to physical stressors, making at least some species in mixed cultures more sensitive than laboratory studies of single species would indicate. Obtain, if possible, a dose-response curve for species diversity (i.e., a combination species richness and equitability) when illuminated by CW 2.45 GHz microwave illumination.

PRIORITIZED LIST OF TASKS AND QUESTIONS

In view of the necessity for adequate dosimetry in the SPS bioeffects research programs to be pursued, the priorities below were assigned on the basis of time flow rather on relative technical merit.

1. DOSIMETRY R & D REQUIREMENTS

Dosimetry and Electro-magnetic Field Workshop.- First priority is assigned to the Workshop because its implementation will require the longest lead time. The Workshop is an important activity because its proposed format, described below, will permit the most rapid and efficient presentation, interchange, and dissemination of information among those concerned with microwave dosimetry.

General Objectives of Workshop: Examine dosimetry needs specific to SPS, survey prior and current dosimetry R & D (both Government-sponsored and commercial) for possible applicability to SPS. Recommendations can then be made to determine and provide what dosimetry R & D should be supported with SPS funding.

Workshop Format: A Dosimetry Advisory Committee should be appointed to work toward the objectives above. The Workshop should be conducted in an informal, round-table, but business-like committee environment. Surveys of specific topics related to the objectives should be solicited from qualified people for presentation to the Advisory Committee. These surveys should be of pertinent dosimetry topics, rather than detailed technical reports on specific projects, such as the papers given at typical scientific meetings, and should be focused toward the stated objectives of the Workshop. Appropriate working subgroups of the Advisory Committee should be set up and tasked to evaluate the information on each topic and to formulate initial, specific recommendations regarding future R & D on SPS related dosimetry. The Advisory Committee as a whole, can then perform an initial integration of the subgroup recommendations.

Initial Partial List of Possible Topics:

Statement of problem: A brief review of the biological and ecological concerns related to the SPS, including possible rectenna sites; levels of incident power density; typical animal and plant species of interest; NASA/DOE SPS planning (technical, funding, phasing, etc.); and the objectives of the Workshop. Suggested presenters: Appropriate NASA, JPL, and DOE personnel.

Current R & D on Em-field measuring instrumentation, dosimeters, and techniques: A group of surveys of recent or ongoing developments on microwave field measurement techniques, nonperturbing probes, noninvasive dosimeters, calorimetric techniques, n-port coupler techniques, and their possible use and limitations for SPS work. Suggested presenters: Appropriate people from the National Bureau of Standards.

Current R & D on methods and instrumentation for determing internal dose-rate distributions and their applicability to animal and plant species of SPS interest: These surveys should include review of analytic modeling and scaling, dose-rate measurement methodologies such as scanning infrared thermography on carcasses and phantoms, and applicability to representative species of mammals, insects, reptiles, birds, and plants of SPS interest. Suggested presenters: Selected investigators on these topics.

Timetable for Workshop: Based on experience in planning and organizing scientific conferences, involving a relatively small number of scientists and other active participants (estimated total of approximately 50 persons), it should be possible to convene the Workshop in approximately six months from the initial planning date, and to document the significant conclusions and recommendations thereof within an additional two months, yielding a total duration of about eight months. However, depending largely on the prior commitments and preparation periods needed by the presenters, it may be possible to shorten the total duration significantly.

Funding Requirements: Since the Workshop is not to be the usual professional-society-sponsored meeting,

but rather is to provide recommendations regarding specific dosimetry R & D subjects, that would require support with SPS related funding, it will be necessary for the government to finance the relevant activities of many of the nongovernment personnel to be invited as active participants (committee and subcommittee members, presenters, and others whose attendance would contribute significantly toward achieving the objectives of the Workshop).

For estimation purposes, it was assumed that a total of 35 active nongovernment participants would require reimbursement for four days of participation, i.e., for three days attendance plus one travel day, comprising a total of 140 person-days. The following reimbursement rates were also assumed:

- $200/person-day as a consultant
- An average of $300/round trip per participant for air travel
- $50/person-day for lodging, meals, and surface transportation.

The figures above total $45,500. Allowing an additional 10% for unforeseen contingencies, yields a total estimate of approximately $50,000.

Survey and Analysis of Extant Dosimetry R & D. - Concurrent with the planning and organization of the Workshop, it is important to conduct a complementary survey of prior and current developments in microwave dosimetry and to analyze such developments for their relevance and potential applicability to SPS related bio-effects research. The survey and analysis will include recent developments of novel techniques and instrumentation for: measuring dose rates (SARs) and internal distributions thereof in appropriate animals, plants, and "phantoms"; modeling, scaling, and interspecies extrapolation; and characterizing the electro-magnetic field distributions in the vicinity of complex structures. These developments will be examined for their relative importance and potential utility within the time frame for decision on SPS implementation.

Although the Workshop will treat many of the dosimetry topics of importance, the thrust of this survey and analysis task will be different, in that appraisal

of the state of the art in dosimetry will be started earlier than is possible with a workshop format, and, in fact, the initial findings will contribute significantly toward setting the direction and increasing the effectiveness of the Workshop. Also, the survey will be broader in scope than the Workshop in that it will include concepts, developments, and instrumentation that would be difficult to treat adequately in the Workshop.

The duration of this task will be approximately eight months; its cost is estimated to be $45,000 based on approximately 0.9 person-year and preparation of the requisite documentation.

R & D Program Recommendations for Dosimetry. - This task will be devoted to integration of the conclusions and recommendations arising out of the Workshop and the concurrent survey and analysis. The results of this task will be documented in the form of prioritized R & D program-element recommendations with appropriate detailed supporting information.

The task will require approximately two months to complete, and will cost about $5,000, based on 0.1 person-year of effort and documentation preparation.

2. PHASE A FACILITIES

Definition of Phase A Experiments. - The starting point for coordination of the Phase A facilities and dosimetry is to identify all relevant efforts and their details, such as where the research will take place, the type of research, what facilities exist already, what is to be acquired, etc.

Identify Existing Facilities. - In parallel with the above task, a complementary effort will be of value. This effort will involve the acquisition and documentation of information pertaining to existing microwave equipment and facilities that are directly relevant to the SPS program, such as CW 2.45 GHz, high-power generators and anechoic chambers, and their suitability with or without modification for the present program.

Identify New Facility Component Suppliers. - If new facilities, or modifications of existing facilities, are required, it will be beneficial to have documented information about suppliers, availability, and price of components needed, e.g., high-power, CW 2.45 GHz sources, waveguide, standard-gain hours, couplers, feeds, power meters, microwave absorber material, anechoic chambers, etc.

New Phase A Facilities Design Appraisal. - Again, this is a task that is closely related to the preceding tasks, and is designed to ensure uniformity of approach, technical correctness, relevance to SPS parameters, and viability of interlaboratory comparisons.

Interlaboratory Comparison and Standardization of Fields and Specific Absorption Rates (SARs). - This task is potentially the most important one of all with regard to credibility of exposure situations for all research efforts in the coordinated program. In most prior research on microwave hazards, the exposure field parameters have had the potential of being somewhat in error in terms of absolute values. Such errors and variability will be greatly reduced by the acquisition of field-measuring probes with calibrations traceable directly to the National Bureau of Standards. Use of the same "secondary standard" probes at each research laboratory will provide credibility to the reported exposure parameters.

3. PHASE B FACILITY PLANNING

SPS Receiving Antenna Site Considerations. - It is projected that as many as 100 Satellite Power Systems may ultimately be deployed. A similar number (or possibly 200, according to recent design suggestions) receiving antenna sites will be developed across the United States. It does not appear justified in the initial considerations to attempt to simulate conditions or the ecology at each and every potential site. Rather, attention should be paid to determining the prime candidate sites for the initial rectenna development, and to using this site (or sites) as the basis for the EBF simulation. Characterization of the

ecology at this site is included in this task.

Survey Existing High-Power Microwave Capabilities. - To correctly simulate the SPS parameters, CW sources are required. Further, if 10^4 square meters are illuminated at, say, 10 mW/cm^2, a total microwave power requirement in excess of 10^6 W is needed. Fortunately, the SPS program is spurring considerable research and development on high-power microwave tubes. This task will identify such developments and ascertain suitability, availability, projected costs, etc., of high-power tubes from various manufacturers.

Define Draft Requirements for Ecosystem Balance Facility. - This task is designed to identify and enumerate component elements of a potential EBF. It is unlikely that the EBF will necessarily resemble the one finally chosen. Rather, the task will stimulate ideas on what areas of expertise are likely to be required in the final design of an EBF, and to aid in the selection of an appropriate team of experts having such skills. It will also result in the generation of a draft document that will provide a central focus for the expert design team at a later date. The team may choose a similar or completely different approach to the EBF design.

Survey Existing Ecosystem Research Facilities. - Facilities for investigating potential ecological effects of nonionizing electro-magnetic radiation already exist in the United States. These are quite specific, however. For example, there is the Project Seafarer Ecological Test Facility in Wisconsin, which is used to search for potential effects resulting from Extremely Low Frequencies (ELF). Ecological studies are also being conducted by the Bonneville Power Authority at an Ultra High Voltage (UHV) transmission line test site in Oregon. A survey of these and other ecosystem research facilities will provide valuable background information to be considered in the EBF design.

Species Diversity and Microcosm Studies Results. - It is desirable that plans for an EBF not be drawn up in a complete absence of knowledge of effects of microwaves on whole ecosystems. For this reason, it is recommended

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that two relatively modest research efforts be carried out early in Phase A. These two efforts will look at the effects of microwaves on terraria or small plots, and also at the effects of microwaves on species diversity and composition, again in small terraria or plots. The efforts are described in more detail later in this report. The objective of the present task is to remain cognizant of the continuing results of the two efforts and to utilize this information, where appropriate, in the new EBF design considerations.

Identify Expertise Needed in EBF Design Team. - Results from tasks described above will be used as input to the selection of an appropriate way to approach the design of an EBF. The various types of expertise needed on the design team will be specified for approval by DOE and NASA.

Selection of Expert Design Team. - This task involves the choice of an appropriate design team from among the several options available.

Develop Detailed Plans for Ecosystem Balance Facility. - This task culminates with the generation of a detailed set of design criteria and estimates for the construction and operational costs of the EBF.

Other considerations: One approach that might be of value in predicting effect of microwaves on ecosystems that has not been addressed in the plans presented here, is that computer simulation and modeling of ecosystems may provide information concerning the parametric sensitivity of the system to shifts in various component species. Work already carried out on the effects of microwaves on animals indicates that there are likely to be some species that are more susceptible to the microwaves than others. (This is due to the fact that under those conditions where the long dimension of the animal is approximately 40% of the wavelength of the microwaves, there is a maximum value of the whole body average SAR.) For the present case, it is likely that small animals, such as birds, squirrels, gophers, etc., will have large values of SAR since their dimensions are comparable with a wavelength of CW 2.45 GHz radiation. If the animal species

most sensitive to the microwave illumination, also are important to the balance of the ecosystem, then major effects on the system could be predicted. Such an approach to the ecological effects might prove to be of value in the planning steps for the Phase B facility as well as for assessing potential effects at various receiving antenna sites.

4. MICROCOSM EXPERIMENTS

Literature Review. - The objective of the literature review is to appraise rapidly the relative merits of the two approaches (terrestrial and small plots), to determine whether the shortcomings of these approaches would be likely to prevent significant additions to the insights that can be gained from single species studies. The objective of the design step is to plan one or more experiments that will appraise the responses of entire species assemblages to microwave illumination, with sufficient accuracy to indicate whether the sensitivities of assemblages of species (communities), will markedly differ from the sensitivities of those same species in isolation.

Pilot Sensitivity Studies. - This research has the objective of providing a qualitative indication of those measures indicating an impact of the microwaves on the microcosm. Such measures might be species diversity and composition, microclimatic effects, biomass, phenology, photosynthesis and respiration, materials losses, and regulation.

Experiments with plants and insects would be cost-efficient and should provide meaningful results.

5. SPECIES DIVERSITY AND COMPOSITION

Literature Review. - As for the previous task, the literature review is to determine the best approach to the problem (microcosm versus plots), to become aware of any special details concerning similar studies (not necessarily with microwaves), and to refine the experimental design.

Species Diversity Pilot Studies. - Experiments with plants and insects would be simplest. Use the results of the literature review to obtain an experimental design suitable for obtaining a dose-response curve for species diversity and composition in both plant and insect communities for various illumination levels of microwave radiation.

Estimates for the costs, durations to complete, and the level of effort required for each of the above tasks are given on the PERT Charts and Protocol Tables that follow.

PLANNING CHARTS

8.1 Dosimetry R&D requirements

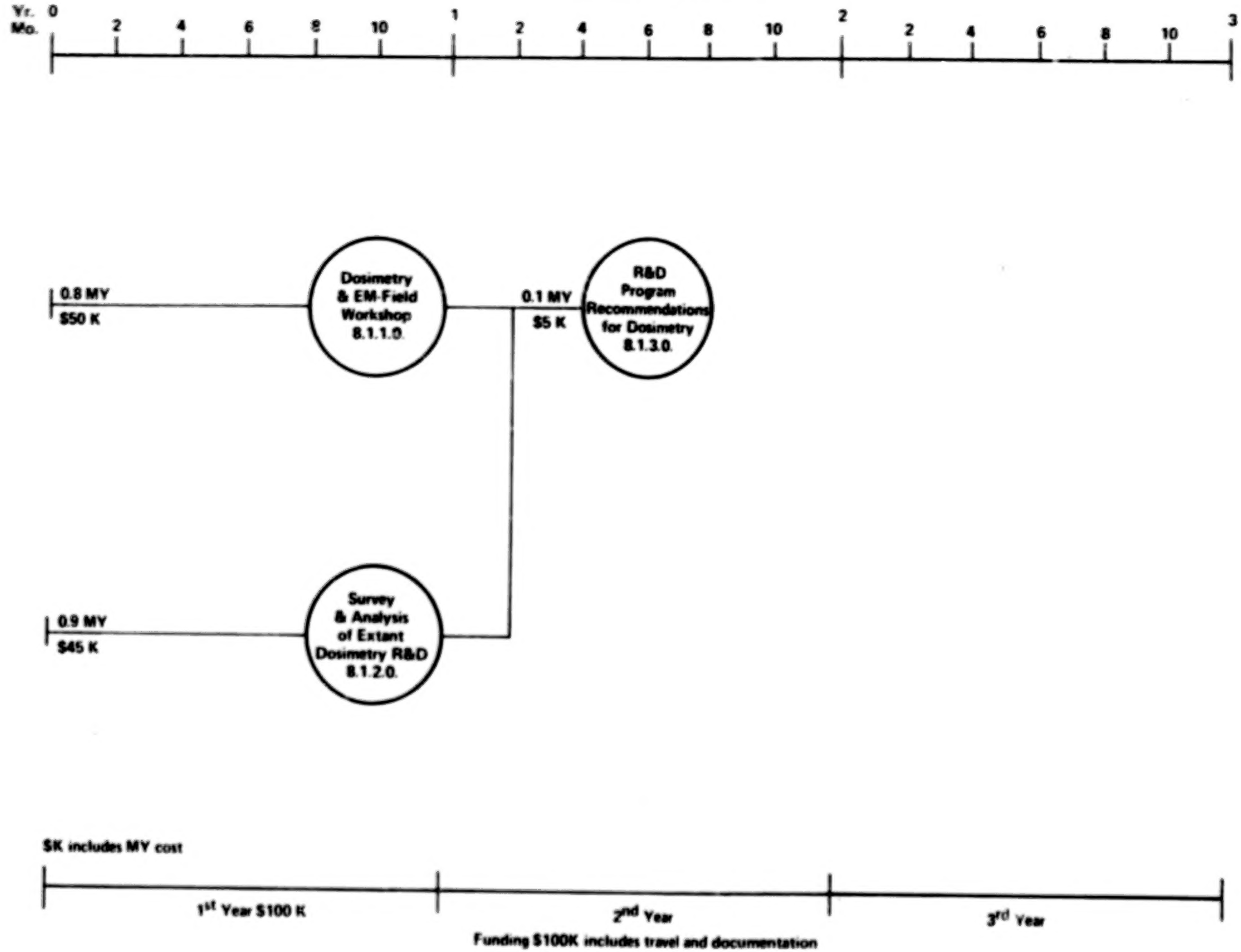

Figure 29

8. DOSIMETRY & FACILITY DEVELOPMENT

8.2 Phase A facilities

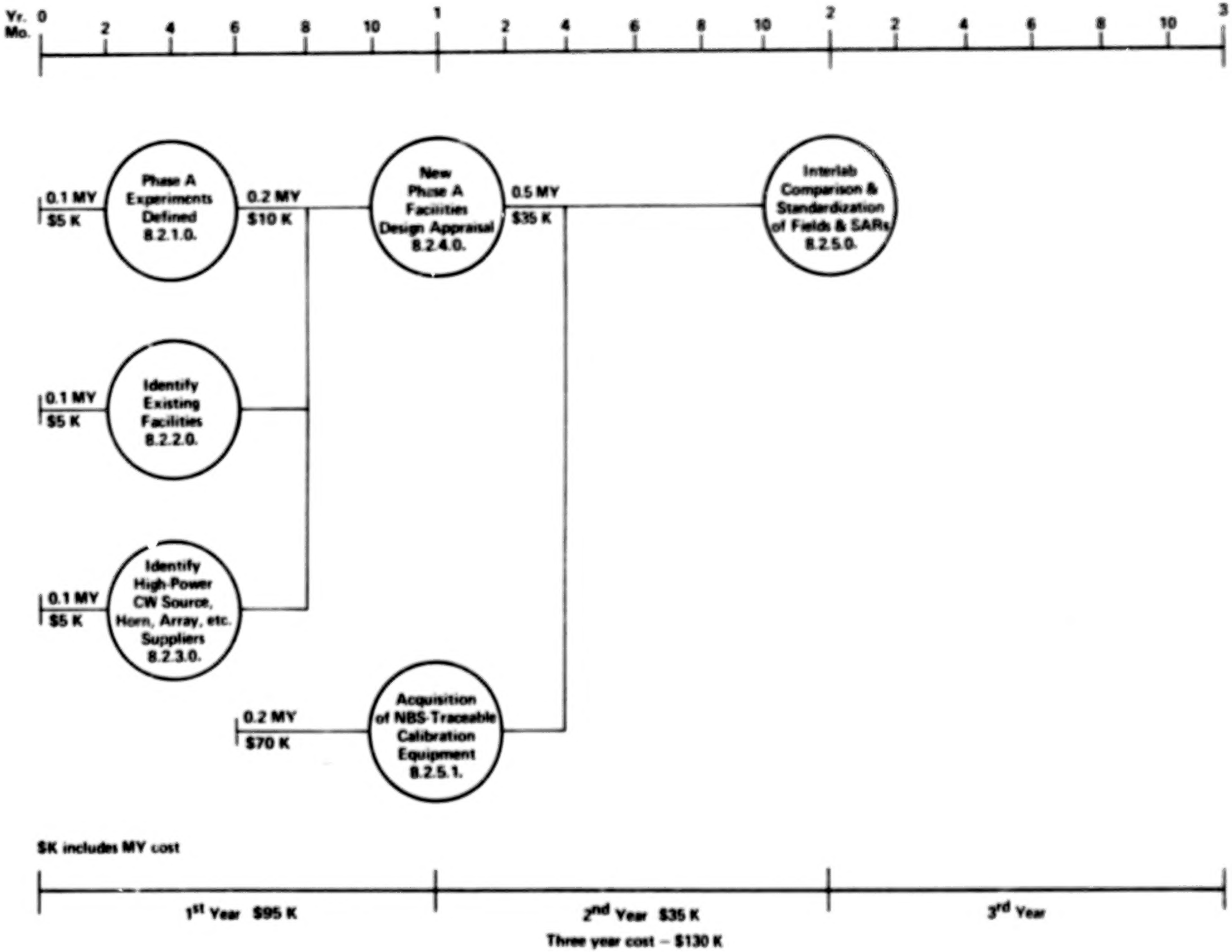

Figure 30

8. DOSIMETRY & FACILITY DEVELOPMENT

8.3 Phase B facility planning

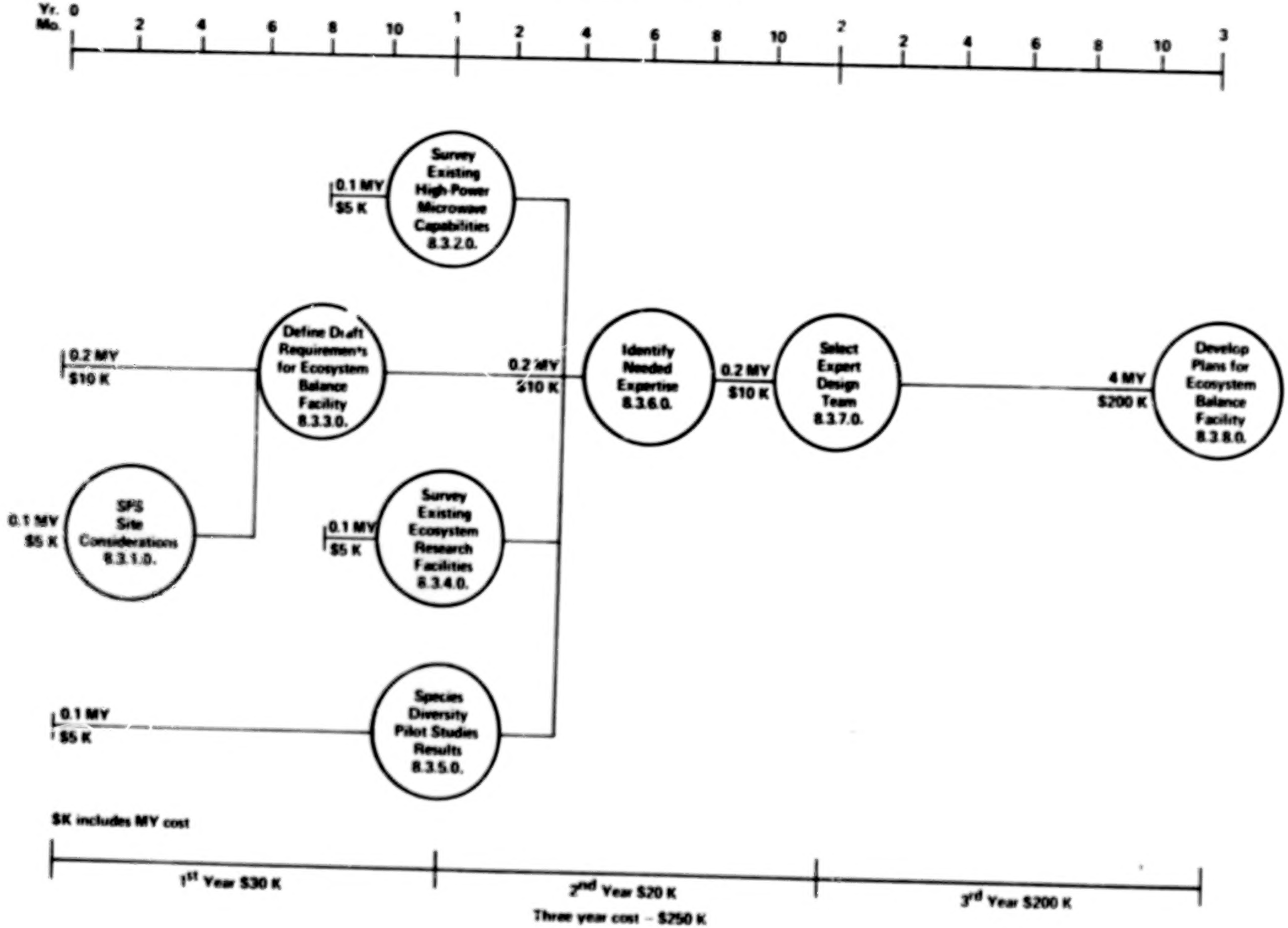

Figure 31

8. DOSIMETRY & FACILITY DEVELOPMENT

8.4 Microcosm experiments: Exploratory studies

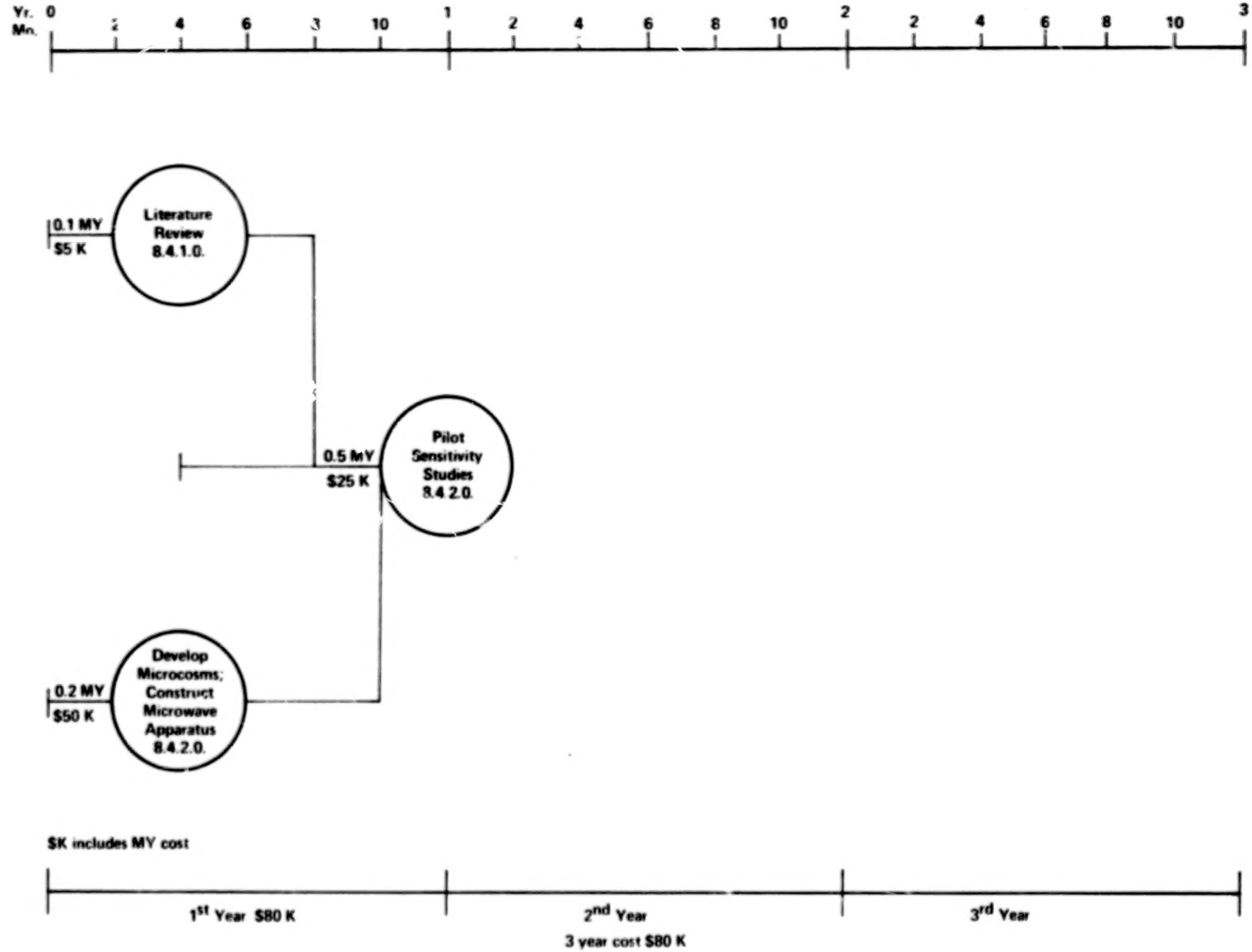

Figure 32

8.5 Species diversity & composition: Pilot experiments

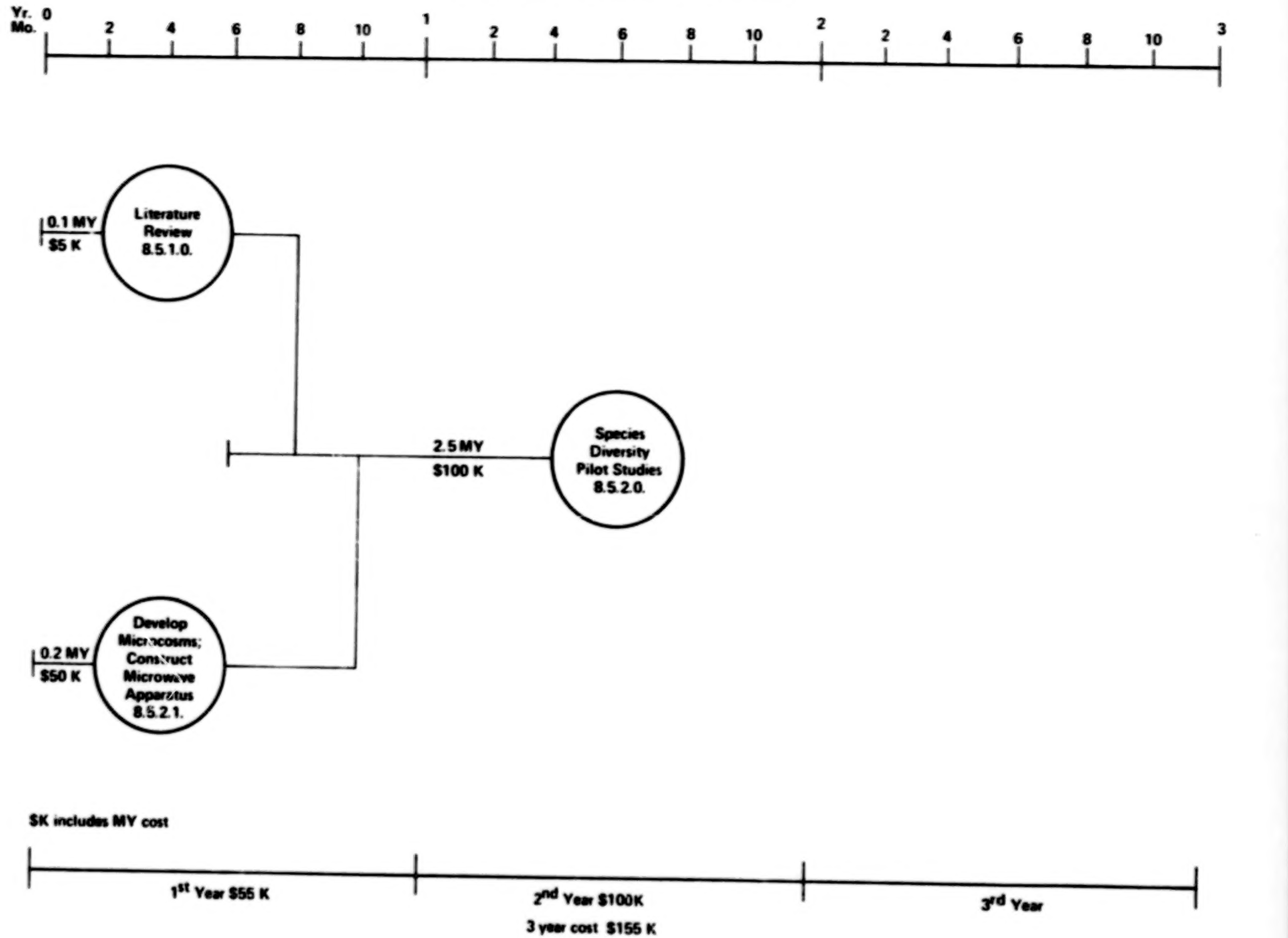

Figure 33

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PROTOCOLS

TABLE 149

8.1 DOSIMETRY R&D REQUIREMENTS

PROTOCOL 8.1.1.0 IMPLEMENTATION OF A DOSIMETRY AND EM-FIELD WORKSHOP

- HYPOTHESIS OR TASK: DETERMINE R&D PROGRAM ELEMENTS ON DOSIMETRY THAT ARE SPECIFICALLY REQUIRED FOR PERFORMING INVESTIGATIONS OF THE BIOLOGICAL AND ECOLOGICAL EFFECTS OF THE SPS, INCLUDING CHARACTERIZATION OF THE ELECTROMAGNETIC (EM) FIELD ENVIRONMENTS AT REPRESENTATIVE RECTENNA SITES.
- APPROACH: AS EARLY IN PHASE A AS POSSIBLE, CONDUCT A GOVERNMENT-SPONSORED DOSIMETRY WORKSHOP, THE RESULTS OF WHICH ARE TO BE INTEGRATED WITH THOSE OF PROTOCOL 8.1.2.0 TO CONSTITUTE A SET OF RECOMMENDATIONS FOR SPECIFIC DOSIMETRY R&D PROGRAM ELEMENTS REQUIRING IMPLEMENTATION WITH SPS-RELATED FUNDS.
- EXPERIMENT TIME:

MONTHS TO COMPLETE	8
MAN YEARS	.8

- COST FOR RESEARCH: $50K
- NEW FACILITIES REQUIRED:

TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
NONE			

TABLE 150

8.1 DOSIMETRY R&D REQUIREMENTS

PROTOCOL 8.1.2.0 SURVEY OF EXTANT DOSIMETRY R&D AND ANALYSIS FOR RELEVANCE TO SPS

- HYPOTHESIS OR TASK: DETERMINE R&D PROGRAM ELEMENTS ON DOSIMETRY THAT ARE SPECIFICALLY REQUIRED FOR PERFORMING INVESTIGATIONS OF THE BIOLOGICAL AND ECOLOGICAL EFFECTS OF THE SPS, INCLUDING CHARACTERIZATION OF THE ELECTROMAGNETIC (EM) FIELD ENVIRONMENTS AT REPRESENTATIVE RECTENNA SITES.
- APPROACH: CONCURRENT WITH THE PLANNING AND IMPLEMENTATION OF THE EM-FIELD AND DOSIMETRY WORKSHOP, ANALYZE THE EXTANT LITERATURE AND ON-GOING PROGRAMS ON DOSIMETRY FOR THEIR POSSIBLE APPLICABILITY TO SPS-RELATED BIOEFFECTS RESEARCH. THIS ANALYSIS WILL INCLUDE RECENT DEVELOPMENTS OF NOVEL TECHNIQUES AND INSTRUMENTATION FOR: MEASURING DOSE RATES AND INTERNAL DISTRIBUTIONS THEREOF IN APPROPRIATE ANIMALS, PLANTS, AND PHANTOMS; MODELLING, SCALING, AND INTER-SPECIES EXTRAPOLATION; AND CHARACTERIZING ELECTROMAGNETIC FIELD DISTRIBUTIONS IN THE VICINITY OF COMPLEX STRUCTURES. THE RESULTS OF THIS ANALYSIS WILL BE INTEGRATED WITH THOSE OF PROTOCOL 8.1.1.0 TO CONSTITUTE A SET OF RECOMMENDATIONS FOR SPECIFIC DOSIMETRY R&D PROGRAM ELEMENTS REQUIRING IMPLEMENTATION WITH SPS-RELATED FUNDS.
- EXPERIMENT TIME:

MONTHS TO COMPLETE	8
MAN YEARS	.9

- COST FOR RESEARCH: $45K
- NEW FACILITIES REQUIRED:

TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
NONE			

TABLE 151

8.1 DOSIMETRY R&D REQUIREMENTS

PROTOCOL 8.1.3.0 DOCUMENTATION OF RECOMMENDATIONS ON DOSIMETRY R&D REQUIREMENTS

- o HYPOTHESIS OR TASK: PREPARE DOCUMENT OF RECOMMENDATIONS FOR R&D PROGRAM ELEMENTS ON DOSIMETRY REQUIRING IMPLEMENTATION WITH SPS-RELATED FUNDS.
- o APPROACH: EVALUATE RESULTS OF PROTOCOLS 8.1.1.0, 8.1.2.0 AND PREPARE DOCUMENTATION OF RECOMMENDATIONS IN APPROPRIATE FORMAT.
- o EXPERIMENT TIME:
  - MONTHS TO COMPLETE 2
  - MAN YEARS .1
- o COST FOR RESEARCH: $5K
- o NEW FACILITIES REQUIRED:

TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
NONE			

TABLE 152

8.2 PHASE A FACILITIES

PROTOCOL 8.2.1.0 PHASE A EXPERIMENTS DEFINED

- HYPOTHESIS OR TASK: THIS TASK IS THE FIRST IN A SERIES OF TASKS DESIGNED TO PROVIDE A STANDARDIZED BASIS FOR COMPARISON OF MICROWAVE ILLUMINATION USED FOR LABORATORY RESEARCH DURING PHASE A THAT IS TO BE PERFORMED IN VARIOUS OTHER CONTRACTED EFFORTS. THE TASK IS TO IDENTIFY, BY CONSULTATION WITH THE FUNDING AGENCIES (DOE/NASA), WHICH SPECIFIC CONTRACTED EFFORTS HAVE BEEN LET, AND WHICH ORGANIZATION WILL BE CONDUCTING THE RESEARCH EFFORT.
- APPROACH: OBTAIN INFORMATION FROM DOE/NASA PERTAINING TO ALL FUNDED RESEARCH EFFORTS COMING UNDER THE AEGIS OF THIS INTEGRATED RESEARCH PROGRAM.
- EXPERIMENT TIME:

MONTHS TO COMPLETE	4
MAN YEARS	.1

- COST FOR RESEARCH: $5K
- NEW FACILITIES REQUIRED:

TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
NONE			

8.2 PHASE A FACILITIES

PROTOCOL 8.2.2.0 IDENTIFY EXISTING FACILITIES

- HYPOTHESIS OR TASK: TO IDENTIFY AND APPRAISE EXISTING MICROWAVE BIOEFFECTS RESEARCH FACILITIES THAT MIGHT BE SUITABLE FOR VARIOUS CONTRACTED RESEARCH EFFORTS PERTAINING TO THE SPS PROGRAM, WITH A VIEW TOWARD INTEGRATING AND STANDARDIZING ALL SUCH MICROWAVE ILLUMINATION RESEARCH FACILITIES FOR THIS PROGRAM.
- APPROACH: OBTAIN INFORMATION BY TELEPHONE AND BY MAIL CONCERNING EXTANT MICROWAVE (2.45 GH_Z, CW, HIGH POWER) EQUIPMENT AND ASSOCIATED EXPOSURE FACILITIES FROM VARIOUS INVESTIGATORS PRESENTLY CONDUCTING RESEARCH ON MICROWAVE HAZARDS.
- EXPERIMENT TIME:

MONTHS TO COMPLETE	4
MAN YEARS	.1

- COST FOR RESEARCH: $5K
- NEW FACILITIES REQUIRED:

TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
NONE			

TABLE 154

8.2 PHASE A FACILITIES

PROTOCOL 8.2.3.0 IDENTIFY NEW FACILITY COMPONENT SUPPLIERS

- HYPOTHESIS OR TASK: NEW MICROWAVE ILLUMINATION FACILITIES WILL PROBABLY BE REQUIRED BY SOME RESEARCH CONTRACTORS IN PHASE A INVESTIGATIONS. IF THESE INVESTIGATORS HAVE NOT HAD EXPERIENCE IN MICROWAVE EFFECTS RESEARCH IT IS POSSIBLE THAT THEY MAY ENCOUNTER DIFFICULTIES IN THE SELECTION AND CONSTRUCTION OF MICROWAVE EXPOSURE FACILITIES THAT ARE COMPATIBLE WITH THE SPS PROGRAM PARAMETERS AND WITH OTHER EXISTING FACILITIES. THE OBJECTIVE OF THIS TASK IS TO COMPILE A DIRECTORY OF SUPPLIERS OF COMPONENTS (HIGH-POWER 2.45 GHz CW SOURCES, STANDARD-GAIN HORNS, FEEDS, COUPLERS, POWER METERS, ARRAYS, ETC.), WHICH CAN BE PURCHASED AS OFF-THE-SHELF ITEMS OR ALTERNATIVELY AS SPECIAL-ORDER ITEMS.
- APPROACH: DOCUMENT SUITABLE COMPONENTS AND THEIR SUPPLIERS. VERIFY AVAILABILITY, DELIVERY TIMES, COSTS, ETC. WITH SUPPLIERS.
- EXPERIMENT TIME:

MONTHS TO COMPLETE	4
MAN YEARS	.1

- COST FOR RESEARCH: $5K
- NEW FACILITIES REQUIRED:

TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
NONE			

TABLE 155

8.2 PHASE A FACILITIES

PROTOCOL 8.2.4.0 NEW PHASE A FACILITIES DESIGN APPRAISAL

- o HYPOTHESIS OR TASK: TO ENSURE THAT THE DESIGN OF NEW FACILITIES CONFORMS WITH SPS-PROGRAM PARAMETERS AND ALSO WITH OTHER EXISTING FACILITIES.
- o APPROACH: PROVIDE CONSULTATIVE SUPPORT TO DOE/NASA TO ENSURE UNIFORMITY OF APPROACH, TECHNICAL CORRECTNESS, AND VIABILITY OF INTERLABORATORY COMPARISONS FOR NEW MICROWAVE ILLUMINATION FACILITIES.
- o EXPERIMENT TIME:

MONTHS TO COMPLETE	8
MAN YEARS	.2

- o COST FOR RESEARCH: $10K
- o NEW FACILITIES REQUIRED:

TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
NONE			

TABLE 156

8.2 PHASE A FACILITIES

PROTOCOL 8.2.5.0 INTERLABORATORY COMPARISON AND STANDARDIZATION OF FIELDS AND SPECIFIC ABSORPTION RATES (SARS)

- <u>HYPOTHESIS OR TASK</u>: IT IS OF CRITICAL IMPORTANCE TO THE CORRECT CONDUCT OF AN INTEGRATED RESEARCH PROGRAM OF THIS MAGNITUDE THAT THE CREDIBILITY OF THE MEASUREMENTS OF ACTUAL FIELD EXPOSURES AND THE ASSOCIATED WITHIN-TISSUE SARS BE HIGH. IN ALL PRIOR RESEARCH EFFORTS ON MICROWAVE HAZARDS, SUCH HAS FREQUENTLY NOT BEEN THE CASE, LEADING TO MUCH FUROR AND CONTROVERSY. TO ENSURE THE ONGOING VIABILITY OF THE PROPOSED SPS PROGRAM, IT IS IMPERATIVE THAT SUCH CONTROVERSY BE AVERTED WHEREVER POSSIBLE.
- <u>APPROACH</u>: ACQUIRE FIELD-MEASURING PROBES WITH CALIBRATIONS TRACEABLE TO NATIONAL BUREAU OF STANDARDS (NBS). USE THSE PROBES IN EACH OF THE COLLABORATING LABORATORIES TO CHARACTERIZE FULLY AND UNEQUIVOCALLY THE ILLUMINATION FIELDS AND TO CALIBRATE THE MICROWAVE EQUIPMENT WITH RESPECT TO THE FIELDS PRODUCED. ACQUIRE A THERMOGRAPHIC CAMERA AND REQUISITE ANCILLARY EQUIPMENT AND NON-PERTURBING TEMPERATURE PROBES AND CONDUCT STANDARDIZATION MEASUREMENTS OF SARS IN VARIOUS PHANTOMS AND CARCASSES. USE THIS EQUIPMENT IN EACH OF THE COLLABORATING LABORATORIES TO CHARACTERIZE SARS.
- <u>EXPERIMENT TIME</u>: MONTHS TO COMPLETE 12 MAN YEARS .5
- <u>COST FOR RESEARCH</u>: $35K
- <u>NEW FACILITIES REQUIRED</u>:

	TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
8.2.5.1	NBS-TRACEABLE FIELD PROBES	$10K	---	6 MONTHS
8.2.5.2	THERMOGRAPHIC CAMERA	$40K	---	6 MONTHS
8.2.5.3	TEMPERATURE PROBE	$10K	---	6 MONTHS

TABLE 157

8.3 PHASE B FACILITY PLANNING

PROTOCOL 8.3.1.0 SPS RECEIVING ANTENNA SITE CONSIDERATIONS

- HYPOTHESIS OR TASK: TO DEVELOP DETAILED PLANS FOR AN ECOSYSTEMS BALANCE FACILITY (EBF) TO BE CONSTRUCTED IN PHASE B AND OPERATED IN PHASE C TO STUDY THE ALTERATIONS PRODUCED IN COMBINED ELEMENTS OF AN ECOLOGICAL SYSTEM AND TO FIELD TEST SIMULATED OPERATIONAL CONDITIONS UNDER VARIOUS ENVIRONMENTAL MODES, IT IS NECESSARY FIRSTLY TO IDENTIFY THE MOST LIKELY CANDIDATE SITES FOR THE RECEIVING ANTENNA ARRAY.
- APPROACH: BY MEANS OF CONSULTATION WITH DOE/NASA AND/OR THEIR CONTRACTORS, DETERMINE THE MOST LIKELY CANDIDATE SITES OR REGIONAL LOCATIONS FOR THE RECEIVING ANTENNA ARRAY. CHARACTERIZE THE ECOLOGY LIKELY TO EXIST AT SUCH A SITE OR SITES.
- EXPERIMENT TIME:

MONTHS TO COMPLETE	3
MAN YEARS	.1

- COST FOR RESEARCH: $5K
- NEW FACILITIES REQUIRED:

TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
NONE			

TABLE 158

8.3 PHASE B FACILITY PLANNING

PROTOCOL 8.3.2.0 SURVEY EXISTING HIGH-POWER MICROWAVE CAPABILITIES

- HYPOTHESIS OR TASK: PRELIMINARY SUGGESTIONS FOR AN EBF INDICATE SOME 10^4 SQUARE METERS UNDER ILLUMINATION. IF AN ESTIMATE OF POWER DENSITY OF 10 mW/cm^2 IS ASSUMED, A TOTAL MICROWAVE POWER REQUIREMENT OF 10^6 IS OBTAINED. THE OBJECTIVE OF THIS TASK IS TO ASCERTAIN HOW SUCH POWER CAN BE REALIZED AND WHERE THE NECESSARY ENGINEERING AND MANUFACTURING CAPABILITY EXISTS.
- APPROACH: IDENTIFY AND CONSULT WITH MAJOR U. S. COMPANIES HAVING EXPERTISE IN HIGH-POWER, CW, 2.45 GHz MICROWAVE GENERATING EQUIPMENT. CATALOG GENERAL AVAILABILITY, COSTS, PREDICTED DEVELOPMENTS, ETC. OF HIGH-POWER TUBES.
- EXPERIMENT TIME:

MONTHS TO COMPLETE	4
MAN YEARS	.1

- COST FOR RESEARCH: $5K
- NEW FACILITIES REQUIRED:

TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
NONE			

TABLE 159

8.3 PHASE B FACILITY PLANNING

PROTOCOL 8.3.3.0 DEFINE DRAFT REQUIREMENTS FOR ECOSYSTEM BALANCE FACILITY

- HYPOTHESIS OR TASK: THE OBJECTIVE OF THIS TASK IS TO IDENTIFY AS MANY ELEMENTS OF A POTENTIAL EBF AS POSSIBLE. THIS IS NECESSARY TO AID IN THE IDENTIFICATION SELECTION OF AN EXPERT DESIGN TEAM THAT WILL DEVELOP THE PLANS FOR AN EBF AT A LATER STAGE.
- APPROACH: COMPILE A DRAFT DOCUMENT DETAILING POTENTIAL QUESTIONS TO WHICH THE EBF IS TO PROVIDE ANSWERS, POSSIBLE WAYS AN EBF MIGHT BE CONFIGURED TO PROVIDE SUCH ANSWERS, AND THE VARIOUS AREAS OF EXPERTISE NEEDED TO DESIGN SUCH A FACILITY. THE DOCUMENT IS ALSO TO PERFORM THE FUNCTION OF AN OUTLINE "STRAWMAN" FOR LATER CONSIDERATION BY AN EXPERT PANEL, WHICH MAY CHOOSE A SIMILAR OR PERHAPS COMPLETELY DIFFERENT APPROACH.
- EXPERIMENT TIME:

MONTHS TO COMPLETE	6
MAN YEARS	.2

- COST FOR RESEARCH: $10K
- NEW FACILITIES REQUIRED:

TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
NONE			

TABLE 160

8.3 PHASE B FACILITY PLANNING

PROTOCOL 8.3.4.0 SURVEY EXISTING ECOSYSTEM RESEARCH FACILITIES

- HYPOTHESIS OR TASK: THE OBJECTIVES OF THIS TASK ARE TO OBTAIN FAMILIARITY WITH EXISTING ECOSYSTEM RESEARCH FACILITIES IN THE U.S., ASCERTAIN THE TYPES OF QUESTIONS THEY WERE DESIGNED TO ANSWER, ASSESS HOW SUCCESSFUL THEY HAVE BEEN OVERALL, OBTAIN SUGGESTIONS FROM PERSONNEL ASSOCIATED WITH THEM THAT MAY BE OF VALUE WITH REGARD TO THE SPS-RELATED EBF.
- APPROACH: IDENTIFY AND VISIT EXISTING U.S. ECOSYSTEM RESEARCH FACILITIES THAT SEEM TO PERTAIN TO THE POTENTIAL EBF FOR THE SPS PROGRAM. OBTAIN DESCRIPTIVE INFORMATION ABOUT SUCH FACILITIES, THEIR CAPABILITY AND COVERAGE. DOCUMENT AND TABULATE FINDINGS ABOUT THE FACILITIES.
- EXPERIMENT TIME:

MONTHS TO COMPLETE	4
MAN YEARS	.1

- COST FOR RESEARCH: $5K
- NEW FACILITIES REQUIRED:

TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
NONE			

TABLE 161

8.3 PHASE B FACILITY PLANNING

PROTOCOL 8.3.5.0 SPECIES DIVERSITY AND MICROCOSM STUDIES RESULTS

- HYPOTHESIS OR TASK: IMPORTANT INPUTS TO THE EBF DESIGN PROCESS ARE RELIABLE DATA ON POTENTIAL ECOSYSTEM EFFECTS RESULTING FROM MICROWAVE RADIATION. PROTOCOLS 8.4.2.0 AND 8.5.2.0 ARE CONCERNED WITH OBTAINING PRELIMINARY OR PILOT EXPERIMENTAL DATA ON SUCH EFFECTS USING MICROCOSMS.
- APPROACH: FOLLOW CLOSELY THE CONTRACTED RESEARCH ON MICROCOSMS AND OBTAIN AS MUCH INFORMATION ON THE PROGRESS AND OUTCOME OF THE EXPERIMENTS AS POSSIBLE. OBTAIN COPIES OF INTERIM AND FINAL REPORTS FOR INPUT TO THE EBF DESIGN TEAM.
- EXPERIMENT TIME:

MONTHS TO COMPLETE	12
MAN YEARS	.1

- COST FOR RESEARCH: $5K
- NEW FACILITIES REQUIRED:

TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
NONE			

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TABLE 162

8.3 PHASE B FACILITY PLANNING

PROTOCOL 8.3.6.0 IDENTIFY EXPERTISE NEEDED IN EBF DESIGN TEAM

- o HYPOTHESIS OR TASK: IT IS ENVISAGED THAT THE EBF DESIGN TEAM WILL BE RESPONSIBLE FOR DRAWING UP A DOCUMENT AND PLANS CONTAINING DETAILED SPECIFICATIONS AND CRITERIA TO BE EMPLOYED IN AN RFP THAT WILL BE ISSUED IN PHASE B. THE DESIGN TEAM SHOULD INCORPORATE PERSONS QUALIFIED IN EACH OF THE TECHNICAL AREAS THAT WILL BE INVOLVED IN THE OPERATION AND CONSTRUCTION OF THE EBF AS WELL AS PERSONS KNOWLEDGEABLE ABOUT THE DRAFTING OF DESIGN CRITERIA, LEGAL ASPECTS OF CODES, AND OTHER AREAS.
- o APPROACH: CONSULT WITH DOE/NASA ON FINDINGS CONCERNING THE MULTIPLICITY OF CONSIDERATIONS OBTAINED AS A RESULT OF PROTOCOLS 8.3.1.0 THROUGH 8.3.5.0. RECOMMEND AND DOCUMENT THOSE AREAS OF EXPERTISE DEEMED NECESSARY IN MEMBERS OF A DESIGN TEAM FOR AN EBF.
- o EXPERIMENT TIME:

MONTHS TO COMPLETE	6
MAN YEARS	.2

- o COST FOR RESEARCH: $10K
- o NEW FACILITIES REQUIRED:

TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
NONE			

8.3 PHASE B FACILITY PLANNING

PROTOCOL 8.3.7.0 SELECT EXPERT DESIGN TEAM FOR EBF

- HYPOTHESIS OR TASK: SEVERAL OPTIONS EXIST FOR THE FORMATION OF AN EXPERT DESIGN TEAM. THE TEAM MIGHT COMPRISE IN-HOUSE GOVERNMENT EXPERTS, POSSIBLY FROM SEVERAL AGENCIES, OR MIGHT BE CONTRACTED TO OUTSIDE COMPANIES. IT MIGHT ALSO BE INSTITUTED IN THE FORM OF A COMMITTEE WITH BOTH GOVERNMENT AND NON-GOVERNMENT MEMBERS. THE OBJECTIVE OF THIS TASK IS TO SELECT AMONG THE ALTERNATIVES AND TO ASSEMBLE A STRONG DESIGN TEAM CAPABLE OF FULFILLING THE DESIGN MANDATE.
- APPROACH: CONSULT WITH DOE/NASA ON THE GENERATION OF AN RFP CONCERNING THE SELECTION OF A DESIGN TEAM VIA ONE CONTRACT OR SUBCONTRACT, OR ALTERNATIVELY ON THE ASSEMBLING OF A SELECTED TEAM OF EXPERTS ON A SPECIALLY FORMED COMMITTEE UNDER DOE/NASA AUSPICES.
- EXPERIMENT TIME:

MONTHS TO COMPLETE	6
MAN YEARS	.2

- COST FOR RESEARCH: $10K
- NEW FACILITIES REQUIRED:

TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
NONE			

TABLE 164

8.3 PHASE B FACILITY PLANNING

PROTOCOL 8.3.8.0 DEVELOP DETAILED PLANS FOR ECOSYSTEM BALANCE FACILITY

- o HYPOTHESIS OR TASK: THE OBJECTIVE OF THIS TASK IS TO DEVELOP A DETAILED SET OF DESIGN CRITERIA SUITABLE FOR INCORPORATION INTO AN RFP THAT WILL LEAD TO A CONTRACT OR CONTRACTS BEING AWARDED FOR THE CONSTRUCTION OF AN EBF. THE RESULTS OF TASKS CARRIED OUT UNDER PREVIOUS PROTOCOLS IN THE 8.3 SERIES WILL HAVE RESULTED IN THE SELECTION OF AN APPROPRIATE DESIGN TEAM AND IN THE GENERATION OF A PRELIMINARY DRAFT ("STRAWMAN") OF A POSSIBLE EBF DESIGN.
- o APPROACH: USE THE STRAWMAN DOCUMENT AS THE BASIS FOR DECIDING ON AN OVERALL APPROACH TO THE EBF DESIGN. ONCE AN OVERALL DESIGN HAS BEEN ESTABLISHED, ALLOCATE TASKS ACCORDING TO EXPERTISE OF THE DESIGN TEAM MEMBERS. CONDUCT PERIODIC REVIEW MEETINGS TO ENSURE CRITERIA ARE INTEGRATED. GENERATE A FINAL DOCUMENT INCORPORATING ALL RECOMMENDED DESIGN CRITERIA AND PLANS.
- o EXPERIMENT TIME:

MONTHS TO COMPLETE	12
MAN YEARS	4

- o COST FOR RESEARCH: $200K
- o NEW FACILITIES REQUIRED:

  NONE

TABLE 165

8.4 MICROCOSM EXPERIMENTS: EXPLORATORY STUDIES

PROTOCOL 8.4.1.0 LITERATURE REVIEW

- HYPOTHESIS OR TASK: ECOSYSTEMS HAVE CHARACTERISTICS THAT DESCRIBE INTERRELATIONSHIPS AMONG THE SUMS OF THE ORGANISMS COMPRISING THEM. FOR EXAMPLE, DIVERSITY AND REDUNDANCY ARE MEASURES OF THE SYSTEM AS A WHOLE. MANY OTHER SYSTEM MEASURES ALSO EXIST. DIVERSITY, A QUANTIFIABLE INDEX THAT CHANGES WITH STRESS, IS A MEASURE OF THE DISTRIBUTION OF THE KINDS AND NUMBERS OF VARIOUS SPECIES. SYSTEMS THAT ARE UNBALANCED BY POLLUTION SHOW A REDUCTION IN DIVERSITY AND AN INCREASE IN THE NUMBER OF THE DOMINANT SPECIES. REDUNDANCY IS A CHARACTERISTIC OF AN ECOSYSTEM IN WHICH THE SAME SPECIES CAN BE FOUND UNDER A WIDE RANGE OF ENVIRONMENTAL CONDITIONS AND CAN TAKE OVER IMPORTANT ECOSYSTEM FUNCTIONS, E.G., PHOTOSYNTHESIS, AS ENVIRONMENTAL CONDITIONS CHANGE. PRELIMINARY DATA ON THE EFFECTS OF MICROWAVE RADIATION ON ECOSYSTEM PARAMETERS ARE VIRTUALLY NONEXISTENT. THE OBJECTIVE OF THIS LITERATURE REVIEW TASK IS TO APPRAISE WHICH SYSTEM PARAMETERS ARE MOST LIKELY CANDIDATES FOR EXPLORATORY STUDIES USING MICROCOSM APPROACHES TO DETERMINE WHETHER AND AT WHAT LEVELS CONSPICUOUS INTERACTIONS ARE LIKELY TO EXIST. THESE EXPLORATORY STUDIES ARE NECESSARY TO PROVIDE VALID DATA FOR DECISIONS REGARDING A LARGE-SCALE ECOSYSTEM BALANCE FACILITY.
- APPROACH: CONDUCT A REVIEW OF THE APPROPRIATE EXTANT LITERATURE. COMPUTERIZED LITERATURE SEARCHES WOULD BE HELPFUL BUT NOT ESSENTIAL.
- EXPERIMENT TIME:

MONTHS TO COMPLETE	4
MAN YEARS	.1

- COST FOR RESEARCH: $5K
- NEW FACILITIES REQUIRED:

TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
NONE			

TABLE 166

8.4 MICROCOSM EXPERIMENTS: EXPLORATORY STUDIES

PROTOCOL 8.4.2.0 PILOT SENSITIVITY STUDIES

- HYPOTHESIS OR TASK: THE INTERACTION OF MICROWAVE EFFECTS ON SOILS, AIR AND ORGANISMS MAY INITIATE IMPACTS THAT ARE NOT READILY PREDICTED FROM STUDIES OF EFFECTS OF THESE COMPONENTS IN ISOLATION. MEASURES THAT MIGHT BE INVESTIGATED ARE SPECIES DIVERSITY AND COMPOSITION; MICROCLIMATIC EFFECTS; BIOMASS; PHENOLOGY; PHOTOSYNTHESIS AND RESPIRATION; MATERIALS LOSSES; AND REGULATION. THE OBJECTIVE OF THIS TASK IS TO CARRY OUT ONE OR MORE EXPERIMENTS SELECTED IN PROTOCOL 8.4.1.0 TO APPRAISE RESPONSES OF ENTIRE SPECIES ASSEMBLAGES TO MICROWAVE IRRADIATION WITH SUFFICIENT ACCURACY TO INDICATE WHETHER THE SENSITIVITIES OF ASSEMBLAGES OF SPECIES (COMMUNITIES) WILL MARKEDLY DIFFER FROM THE SENSITIVITIES OF THOSE SAME SPECIES STUDIES IN ISOLATION.
- APPROACH: EXPERIMENTS WITH PLANTS AND INSECTS WOULD BE SIMPLEST. USE TERRARIA, AQUARIA OR PLOTS DEVELOPED AS FACILITY 8.4.2.1 TO OBTAIN RESPONSES OF SYSTEM MEASURES SELECTED UNDER PROTOCOL 8.4.1.0 WHEN THE MICROCOSMS ARE ILLUMINATED WITH VARIOUS LEVELS OF 2.45 GHz CW MICROWAVE RADIATION.
- EXPERIMENT TIME:

MONTHS TO COMPLETE	12
MAN YEARS	.8

- COST FOR RESEARCH: $40K
- NEW FACILITIES REQUIRED:

	TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
8.4.2.1	MICROCOSMS	$20K	---	3 MONTHS
8.4.2.2	MICROWAVE APPARATUS	$20K	---	3 MONTHS

TABLE 167

8.5 SPECIES DIVERSITY & COMPOSITION: PILOT EXPERIMENTS

PROTOCOL 8.5.1.0 LITERATURE REVIEW

- HYPOTHESIS OR TASK: THE INTERACTION OF MICROWAVE EFFECTS ON SOILS, AIR AND ORGANISMS MAY INITIATE IMPACTS THAT ARE NOT READILY PREDICTED FROM STUDIES OF THESE COMPONENTS IN ISOLATION. THE PROBABILITY OF LARGE EFFECTS OF THIS SORT IS LIKELY TO BE SMALL AND THE APPROPRIATE EXPERIMENTAL APPROACH UNCERTAIN. HOWEVER, PRELIMINARY DATA ARE ESSENTIAL FOR USE IN THE DECISION-MAKING PROCESS REGARDING A LARGE-SCALE ECOSYSTEM BALANCE FACILITY. THE OBJECTIVE OF THIS LITERATURE REVIEW TASK IS TO APPRAISE RAPIDLY THE RELATIVE MERITS OF MICROCOSM EXPERIMENTS (TERRARIA, AQUARIA, AND SMALL PLOTS) TO DETERMINE WHETHER SHORTCOMINGS OF THESE APPROACHES WOULD BE LIKELY TO PREVENT SIGNIFICANT ADDITIONS TO THE INSIGHTS THAT CAN BE GAINED FROM SIMPLE SPECIES STUDIES.
- APPROACH: CONDUCT A REVIEW OF THE APPROPRIATE EXTANT LITERATURE. COMPUTERIZED LITERATURE SEARCHES WOULD BE HELPFUL BUT NOT ESSENTIAL.
- EXPERIMENT TIME:

MONTHS TO COMPLETE	4
MAN YEARS	.1

- COST FOR RESEARCH: $5K
- NEW FACILITIES REQUIRED:

  NONE

TABLE 168

8.5 SPECIES DIVERSITY & COMPOSITION: PILOT EXPERIMENTS

PROTOCOL 8.5.2.0 SPECIES DIVERSITY PILOT STUDIES

- o HYPOTHESIS OR TASK: THE NUMBER OF SPECIES PER UNIT AREA AND THE RELATIVE ABUNDANCE OF SPECIES WITHIN BIOLOGICAL COMMUNITIES ARE GENERALLY MORE SENSITIVE INDICATORS OF STRESS THAN ARE CHANGES IN THE PRODUCTIVITY OF THOSE COMMUNITIES. RESISTANT SPECIES TEND TO UTILIZE THE RESOURCES NORMALLY USED BY THE MORE SENSITIVE SPECIES, THEREBY STABILIZING PRODUCTIVITY. MOREOVER, THE PRESENCE OF BIOLOGICAL COMPETITORS CAN ENHANCE THE SENSITIVITY OF ORGANISMS TO PHYSICAL STRESSORS, MAKING AT LEAST SOME SPECIES IN MIXED CULTURES MORE SENSITIVE THAN LABORATORY STUDIES OF SINGLE SPECIES WOULD INDICATE.
- o APPROACH: EXPERIMENTS WITH PLANTS AND INSECTS WOULD BE SIMPLEST. USE THE TERRARIA, AQUARIA OR PLOTS DEVELOPED UNDER PROTOCOL 8.5.1.0 AND FACILITY 8.5.2.1 TO OBTAIN A DOSE-RESPONSE CURVE FOR SPECIES DIVERSITY IN PLANT AND INSECT COMMUNITIES (I.E., A COMBINATION OF SPECIES RICHNESS AND EQUITABILITY) WHEN ILLUMINATED WITH VARIOUS LEVELS OF 2.45 GHz CW MICROWAVE RADIATION.
- o EXPERIMENT TIME:

MONTHS TO COMPLETE	18 (PRELIMINARY DATA IN 9 MONTHS)
MAN YEARS	2.5

- o COST FOR RESEARCH: $100K
- o NEW FACILITIES REQUIRED:

	TYPE	COST $	MAN YEARS	TIME TO ACQUIRE
8.5.2.1	MICROCOSMS	$20K	---	3 MONTHS
8.5.2.2	MICROWAVE APPARATUS	$20K	---	3 MONTHS

MILESTONE AND FUNDING SUMMARY

TABLE 169

MILESTONE AND FUNDING SUMMARY

	PHASE A YEAR 0	1	2	3	COST $K Exper.	Facil.	Question
8.1.0.0 Dosimetry R & D Requirements				∇	--	--	100
8.1.1.0 Implementation of a Dosimetry and EM-Field Workshop		∇			50	--	
8.1.2.0 Survey and Analysis of Extant and Dosimetry R & D		∇			45	--	
8.1.3.0 R & D Program Recommendations for Dosimetry		∇			5	--	
8.2.0.0 Phase A Facilities				∇	--	--	130
8.2.1.0 Phase A Experiments Defined		∇			5	--	
8.2.2.0 Identify Existing Facilities		∇			5	--	
8.2.3.0 Identify High-Power CW Source, Horn, Assay, etc., Suppliers		∇			5	--	
8.2.4.0 New Phase A Facilities Design Appraisal		∇			10	--	
8.2.5.0 Interlaboratory Comparison and Standardization of Fields and SARs				∇	45	60	

TABLE 169. - Continued

	PHASE A YEAR 0	1	2	3	COST $K Exper.	Facil.	Question
8.3.0.0 Phase B Facility Planning				▽	--	---	250
8.3.1.0 SPS Site Considerations			▽		5	---	
8.3.2.0 Survey Existing High Power Microwave Capabilities			▽		5	---	
8.3.3.0 Draft Requirements for EBF			▽		10	---	
8.3.4.0 Survey Existing Ecosystem Research Facilities			▽		5	---	
8 .3.5.0 Species Diversity Pilot Studies Results			▽		5	---	
8.3.6.0 Identify Needed Expertise			▽		10	---	
8.3.7.0 Select Expert Design Team			▽		10	---	
8.3.8.0 Develop Plans for EBF				▽	200	---	
8.4.0.0 Microcosm Experiments: Exploratory Studies		▽			--	---	80
8.4.1.0 Literature Review		▽			5	---	
8.4.2.0 Pilot Sensitivity Studies		▽			35	40	

TABLE 169. - Concluded

	PHASE A YEAR	COST $K		
	0 1 2 3	Exper.	Facil.	Question
8.5.0.0 Species Diversity and Composition: Pilot Experiments	▽	---	---	155
8.5.1.0 Literature Review.	▽	5	---	
8.5.2.0 Species Diveristy Pilot Studies	▽	110	40	

PILOT EXPERIMENTATION

None performed

XI. DERIVED FUNDING REQUIREMENTS

Although the primary purpose of constructing the Research Plan was to define the research to be done, it also determines what the budgetary requirements would be for such an effort. From similar studies done in the past, it was estimated that the cost would be between five and ten million dollars. Without a plan such as that which has been presented, it is difficult to substantiate the need for these amounts of moneys, and it is difficult to describe how they are expected to be dispersed. The pre-study estimates were good, in as much as the funding of all questions, in all categories, totalled $8,887,000.00. This funding, however, is only for the first three years of research, that is, for Phase A. The Phase A research can be anticipated to be much less costly than either Phase B or C, in as much as it is restricted to those experiments dealing with effects of microwaves at one frequency. As mentioned previously, Phase A studies consist of exposing a sample to a specific environmental situation using microwave frequencies and physical characteristics of the SPS power transmission system. The reuslts of that exposure are observed, and then experimentation proceeds to the next effect study. This is done in order to generate as much information as possible within the three year period.

Throughout the development of the research plan, a frequent comment by Principal Investigators, was to point out the importance of the mechanism studies that were not being included. In Phase B, such mechanisms would necessarily be pursued, in order to have some understanding about effects observed in Phase A.

Such mechanism studies cannot be scheduled as they are open-ended in nature, and because of this, a different procedure for program management may be required. The studies will most likely originate from the effect studies completed in Phase A, and the costing of such studies will be generated by proposed research. The cost, however, can be anticipated to be at least twice that which is expended in Phase A; an even more costly endeavour will be those ecological studies necessary to perform in Phase C. Such studies will involve several segments of the ecology, or one entire ecological system in a simulated environment that is closely controlled. These types of experiments will need special facilities similar to Biotron, or Phytotron with attached costs of twenty million dollars or more.

Flexilibility of Approach. - Close to the end of the research plan development, an opportunity was provided to test its usefulness. A requirement arose for an abbreviated research program of a less comprehensive nature than the goal of that presented. By selecting protocols from each of the categories that made use of common facilities, a plan was constructed for the prescribed funding level of $700,000.00 a year for a period of three years. That abbreviated plan is presented in the Appendix of this report, and serves as an example of how the generated protocols can be used to expedite this research without funding all the questions asked.

Annual Cost by Question. - Table 170 shows the annual and total three year funding to the nearest thousand dollars for each of the questions presented in the research plan. Were all the questions funded, that were believed to be important by the consortium members, the research would cost $4,701,000.00 the first year, $2,309,000.00 the second year, and $1,877,000.00 the third year. The high cost of the first year is due to facility build-up, and the lower cost of the third year is due to the work of several questions being completed during the first two years.

Budget Requirement for Various Numbers of Prioritized Questions to be Funded Across All Categories. - The approach to the development of the research plan was done with equal emphasis on each category, because so little knowledge is available about the ecological elements to be affected by the SPS transmission system. The difference in costs between categories is due to estimates associated with experiments described in the protocols, and no cost limitations were placed upon the generators of those protocols. Table 171 provides the cost figures for structuring a research plan, making use of the prioritizations provided by the consortium members. The importance of questions within a category may certainly be disputed, amongst authorities in each field. It can be seen n Part A of Table 171, that the cost of funding all questions f either priority 1 or 2 is not significantly different. For budgetary purposes, then, re-prioritization of questions between and 2, would not seriously affect funding requirements; however, transposing priorities of questions at level 3 or 4 with those of 1 or 2, could significantly affect the required funding.

Part B of Table 171 presents the cost for what is probably realistic situation, where priority questions 1, or 1 and 2, become the accepted funding level, and the question is asked: ow much additional funding would be required to study each rea in greater depth? From Part B, Table 171, it can be seen

TABLE 170

ANNUAL COST FOR PRIORITIZED QUESTIONS IN $K

CATEGORY	QUESTION PRIORITY	YEAR 1	YEAR 2	YEAR 3	TOTAL
Absorbed Dose	1	190	184	157	531
	2	283	202	205	690
Chronic Low Dose	1	205	90	80	375
	2	153	95	65	313
	3	205	90	80	375
	4	205	76	74	355
	5	130	80	60	270
Birds	1	310	108	96	514
	2	299	129	92	520
	3	308	171	143	622
	4	250	41	45	336
	5	255	63	62	380
Heterotherms	1	163	34	41	238
	2	172	68	66	306
Invertebrates	1	108	103	53	264
	2	131	89	43	263
	3	110	72	54	236
	4	115	88	62	265

TABLE 170. - Concluded

CATEGORY	QUESTION PRIORITY	YEAR 1	YEAR 2	YEAR 3	TOTAL
Mycology	1	91	100	---	191
	2	60	71	5	136
	3	79	---	---	79
Plants	1	72	49	47	168
	2	131	51	44	226
	3	198	50	50	298
	4	118	50	53	221
Dosimetry and Facilities	1	100	---	---	100
	2	95	35	---	130
	3	30	20	200	250
	4	80	---	---	80
	5	55	100	---	155
Annual Total		4,701	2,309	1,877	8,887

TABLE 171

$K COST BY NUMBER OF QUESTIONS FUNDED

ACROSS ALL CATEGORIES

PART A

	BY PRIORITY					
Question No.	1	2	3	4	5	ALL
1st Year	1,239	1,324	930	768	440	4,701
2nd Year	668	740	403	255	243	2,309
3rd Year	474	520	527	234	122	1,877
Three Year Cost	2,381	2,584	1,860	1,257	805	8,887

PART B

	MORE THAN ONE QUESTION FUNDED				
Questions	1	1&2	1,2&3	1,2,3&4	1,2,3,4&5
1st Year	1,239	2,563	3,493	4,261	4,701
2nd Year	668	1,408	1,811	2,066	2,309
3rd Year	474	994	1,521	1,755	1,877
Three Year Cost	2,381	4,965	6,825	8,082	8,887

that the total three year cost for priority 1 items across all categories, is $2,381,000.00 and to fund both priorities, 1 and 2, is $4,965,000.00. Adding priority 3 raises the cost to $6,825,000.00; by adding 3 and 4, it comes to $8,082,000.00. As mentioned previously, the cost of funding everything that has been presented is $8,887,000.00. It is not imperative that all experiments or protocols be completed within each question, but no attempt has been made to prioritize the plan at that level. Obviously, adjustments in cost can be made by deleting protocols; however, in some instances, experiments within a question are sequenced in a way that information must be acquired from a preceding protocol, before a subsequent one can be done. The protocols of various questions in various categories can also be manipulated in time sequencing, or for a specific purpose, as was done in the Appendix of this report.

General Discussion. - Frequent comment to the planning charts is that it violates the freedom, usually observed by funding agencies for basic research laboratories, to pursue a likely mechanism after a series of effect studies have been performed. The importance of pursuing the scheduled approach for an SPS program has been discussed earlier. The second most frequent comment is about the rigidity of the research schedule when it is transposed to a milestone chart. The planning chart is simply a means of displaying the anticipated sequence of events, in order to achieve the desired information goals in three years. It does not mean that the same goals might not be achieved with a different experiment sequence. Such adjustments might be necessary for many reasons, such as availability of animals, personnel or facility break-downs. Other comments on the structure of the plan has been the limitation on the microwave frequency and E plane orientation, along with the power densities to be studied. The alternate approach has been suggested that the SPS requirements for information on Biological and Ecological effects be derived from a general Microwave Effects Study. The mechanism of effects would be defined in a way that they could be extrapolated to the SPS system. Such an approach has been used to understand the mechanisms of ionizing radiation. It was estimated that such information could be available, if pursued in that way, by the end of the twenty year period when the SPS system was ready to fly. This, of course, would provide little help to those attempting to define guide-lines for SPS system design.

Another alternative approach to the one presented in this plan, is to immediatley pursue the ecological problem and define the effect on species balance and community response, rather than for individual effects. The plan presented has

scheduled this type of research during Phase C, on the assumption that such studies could be better done if individual responses, if any, were first defined, and also that the facilities required for such ecological studies to be done correctly, would require several years to design, to fund, and to build. In addition, it might be questionable whether the cost of building such facilities was warranted prior to commitment for further studies in 1980. If such ecological studies can be initiated, and delivery of required information assured, serious consideration should be given to doing so. Many of the experiments proposed in this research plan could be well underway and near completion, during the time that such an alternate approach would take to initiate, so perhaps, a safe approach is to pursue both paths.

APPENDIX

BIOLOGICAL AND ECOLOGICAL EFFECTS

OF THE SPS POWER TRANSMISSION BY MICROWAVES

Selected Protocols From the Ames Research Plan

To Formulate An Abbreviated Three Year Program

For a Total Funding of $2,100,00.00

The Ames Research Center Plan. - A plan was developed in the text of this document to define the research, and assess the funding required, to generate as much information as possible in three years, on important questions concerning the effects of the SPS power transmission, on the Biological and Ecological elements in and around the rectenna system. The approach was to segregate those portions of the ecological system which might be affected by the microwave transmission at CW 2.45 GHz into separate categories. Each category was then assigned to an expert in that field of research. The expert may be an authority on that part of the ecological system, or within the field of microwave physics required to define the necessary research. Each category then was assigned a series of critical prioritized questions pertaining to the effect of microwaves on that part of the ecological system. The prioritization was done for each category, with the approach that a limited budget would still allow development of all categories in the research plan, by funding only the highest prioritized questions.

A series of experimental protocols were generated to answer each question, suitable to be released as a single contract. The protocols were then abstracted, and arranged so all experiments would be completed by the end of the three year period, and diagrammed in a PERT fashion, to show the interrelationship between experiments, and the sequence of using common equipment within that particular question. For each experiment, the funding requirement for facilities and research, the time estimated to complete experimentation, and the level of man power needed during that period, was defined. Each protocol is defined by title, and the number by which that protocol can be found or referenced. The funding and man year requirement is shown on the PERT line, denoting the time

period necessary to complete the experiment, and when in the three years, that experiment is performed. Protocols are referenced by a four digit system and can be found in the text of this document; the first digit defines the category; the second digit, the priority of the question; the third digit, the protocol for that question, and the fourth digit refers to a facility requirement of that experiment.

Requirement For An Abbreviated Research Plan. - During the time when the Ames Research Center (ARC) plan was being developed, a funding level was assigned to this portion of the total SPS program, which was below that required to answer all of the priority one questions of all categories. The ARC plan is structured so each question can be issued as a single request for proposal, for the purpose of competitive bidding. This entails considerable additional expense over an approach which would combine questions using common equipment, because it necessitates the duplication of very expensive facilities. The anticipated funding for this program is \$2,100,000.00 over the three year period or \$700,000.00 per year. A plan has been developed in the Appendix to fit within this budgetary limit, by selecting protocols from questions and categories that can make use of common equipment. It is a program based upon what is believed to be the most essential parts of each category, and where the greatest amount of information can be derived for the available funding.

The information sought is that which will better define, or alleviate constraints on design, due to possible Ecological impact or health hazard. Suitably sized restricted areas around the rectenna can obviate the hazard to surrounding populations, but increases the problems associated with site selections. Restricted access to large public land areas used for rectenna sites, could cause problems between those interested in optimal design for power reception and those of the community who are ecologically concerned.

Whether the system be placed in the desert, mountains or plains areas not currently occupied, it will be objectionable to that group of individuals interested in maintaining it as an open space area and preserving as much of the natural environment as possible. An alternative approach is the use of large tracts of privately owned property, leased for the thirty year lifetime period of the system. Such tracts now used for various types of agriculture have already had the natural ecological balance disrupted, and now exist as a system maintained by man. It offers the advantage of being privately owned and, therefore, easier to control access and can be more

easily monitored. With proper design, it is very possible that the agriculture now being conducted upon these sites could be continued in nearly a normal operational mode. At present, there is no confirmed statistical evidence that the microwave levels of illumination at the periphery of the rectenna site or below it would have a deleterious effect on either the flora or fauna. The levels are also below those believed to be hazardous for man, during an eight hour work day. With proper dosimetry and protective garments, it should be possible to work the areas around the rectenna site and even beneath it, at whatever dose might be designated as acceptable in the future.

The selection of protocols for this abbreviated study was made first by reviewing all protocols in the high priority questions from each category and considering those which contributed to the information sought and which could be completed within the dollar budget.

Approach. - The plan is presented as four major experimental efforts, and is composed of protocols abstracted from the full text. Where possible, funding and man power efforts have been used as assigned by the author of that protocol. In some instances, this is not practical, and a reduced level of effort on that particular protocol will be necessary. Hopefully, those parts of the program which have been so reduced, but indicate on completion that more information is required, would be assigned additional funding when available.

Emphasis has also been placed on those protocols which might provide information affecting the design parameters of the SPS system, as well as being pertinent to ecological questions. Table A-1 shows the funding schedule for the three year condensed research program. The selected protocols have been arranged into four groups: first, the Chronic Low Dose Studies that attempt to reproduce effects reported as "non-thermal" as a result of prolonged exposures. Second, the Absorbed Dose Studies which include modeling, and the study of birds and reptiles (Reptiles are used as representative species to study the homeotherms). The third group consists of the Invertebrate Studies using the Bee as an insect model and also looking at representative classes to include other insects, as well as spiders, round-worms, earthworms and the snails and slugs. The fourth group is the Plants and Fungi Study. The study of this last group has been greatly simplified by limiting the study of plants to three genetically stable crop plants, rather than selecting representative species from thousands of wild varieties. The fifth area

TABLE A-1

THREE YEAR FUNDING SCHEDULE FOR A CONDENSED RESEARCH PROGRAM

OF SELECTED PROTOCOLS FROM THE ARC PLAN

"BIOLOGICAL AND ECOLOGICAL EFFECTS OF SPS ENERGY TRANSMISSION BY MICROWAVE"

PROGRAM YEAR	1	2	3	TOTAL FUNDING
CHRONIC LOW DOSE	$170K	$149K	$187K	$506K
ABSORBED DOSE MODELING BIRDS & REPTILES	$258K	$258K	$258K	$722K
INVERTEBRATES BEES & REPRESENTATIVE CLASSES	$106K	$106K	$189K	$401K
PLANTS & FUNGI	$108K	$105K	$51K	$264K
PROGRAMMATIC & DOSIMETRY WORKSHOP	$46K	$72K	$60K	$178K
ANNUAL FUNDING	$688K	$690K	$693K	$2071K

requiring funding, is the Programmatic Aspects associated with conducting the above experiments, and includes arrangements for a dosimetry workshop. The current state of dosimetry is totally inadequate for the purposes of the SPS system and is a long lead time item. During the development of the ARC Research Plan by the consortium members, it became evident that if the research was to be done in academic laboratories, and was to be managed programmatically, the Principal Investigators would require help in preparing the reporting procedures usually employed, to provide visibility into progress and problems. An Interface task to provide such assistance for non-technical aspects of the program has been included.

Chronic Low Doses. - Figure A-1. - Considerable concern has been expressed over the great disparity between the U.S.S.R. acceptable standard of 10 microwatts per square centimeter incident microwave illumination and the American working standard of 10 milliwatts per square centimeter. This thousand fold difference has been contributed to the non-thermal effects purported by the Russian scientists; effects, that in most cases, have not been duplicated in the United States. Recently, it has become clear that many of the experiments performed in Russia are conducted in a manner quite different from those conducted in the United States, in both their exposure methods, and in the degree of control exercised for the experiment. In addition to this, however, many of the very low dose effects reported, are on chronically irradiated animals exposed continuously to these low levels for long periods of time. Such experiments have not been conducted in the United States, and though they have been attempted, these experiments have not received adequate funding to properly duplicate the protocols, as they were developed in Russia. The effects reported by the Eastern block countries at low levels, include changes in electro-encephalograph (EEG) patterns, biochemical changes, cyto-chemical changes and changes in the immunological properties of blood. The Soviet block countries have also expressed concern over the change in the psychological state of workers being exposed to their accepted standards for microwave environments, indicating a neurasthenic problem of listlessness, amotivation, and lack of aggressiveness. The first set of proposed combined experiments are shown in Figure A-1 and the protocols have been chosen in an attempt to provide information on the maximum number of these questionable areas. The chronic low dose studies are performed on mice, rats and rabbits and all rely upon a common set of facilities, composed of the power source, the dosimetry and the chronic exposure chambers. These chronic exposure chambers have been under development for several years at the University of Washington, and were tested

CHRONIC LOW DOSE
MICE, RATS & RABBITS
IN A CW 2.45 GHz ENVIRONMENT

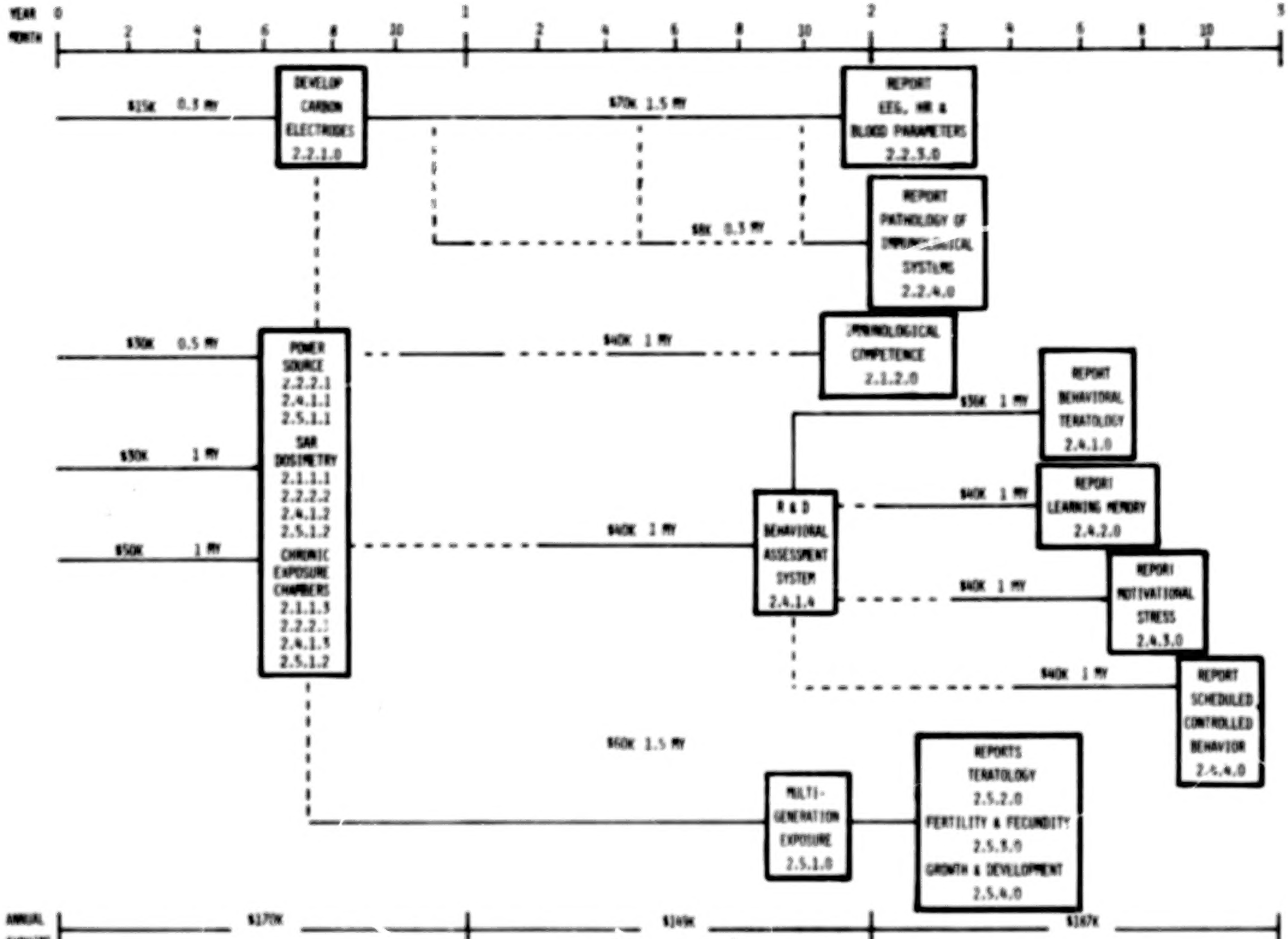


Figure A-1

during the period of the ARC protocol development as one of the pilot experiments. Recent reports from Russia indicate that changes in electro-encephalograph patterns of rabbits have been observed with exposures as low as 10 microwatts per square centimeter. Such an observation, if substantiated, could lead to the lowering of that country's accepted tolerable dose to 1 microwatt per square centimeter. An important aspect of this type of research, however, is that EEG's are usually performed with metal electrodes, and metal electrodes will perturb the field, enhancing energy deposition. The development of carbon electrodes therefore, is a first order priority in this set of experiments, and this, too, has been underway for some time at the University of Washington. These studies are done on rabbits, and during the EEG studies, change in heart rate and some blood parameters can also be measured. These experiments are described in protocol 2.2.3.0. At the end of each chronic exposure period, these animals may be sacrificed, and the pathological studies performed on the immunological systems as described in protocol 2.2.4.0.

The mouse is a desirable species for study of immunological competence as described in 2.1.2.0 and for the multi-generational exposures described in 2.5.1.0, because of rapid maturation and short gestation time. During the multi-generation studies, it should also be possible to perform the observations for teratological changes described in 2.1.2.0, as well as the fertility and fecundity changes described in 2.5.3.0 and of course, the growth and development observations as described in 2.5.4.0. Because of the handling and training characteristics of the rat, it is preferable for the behavioral studies. Table A-2 depicts the anticipated milestone schedule for this group of chronic low dose experiments and shows the annual funding budgeted.

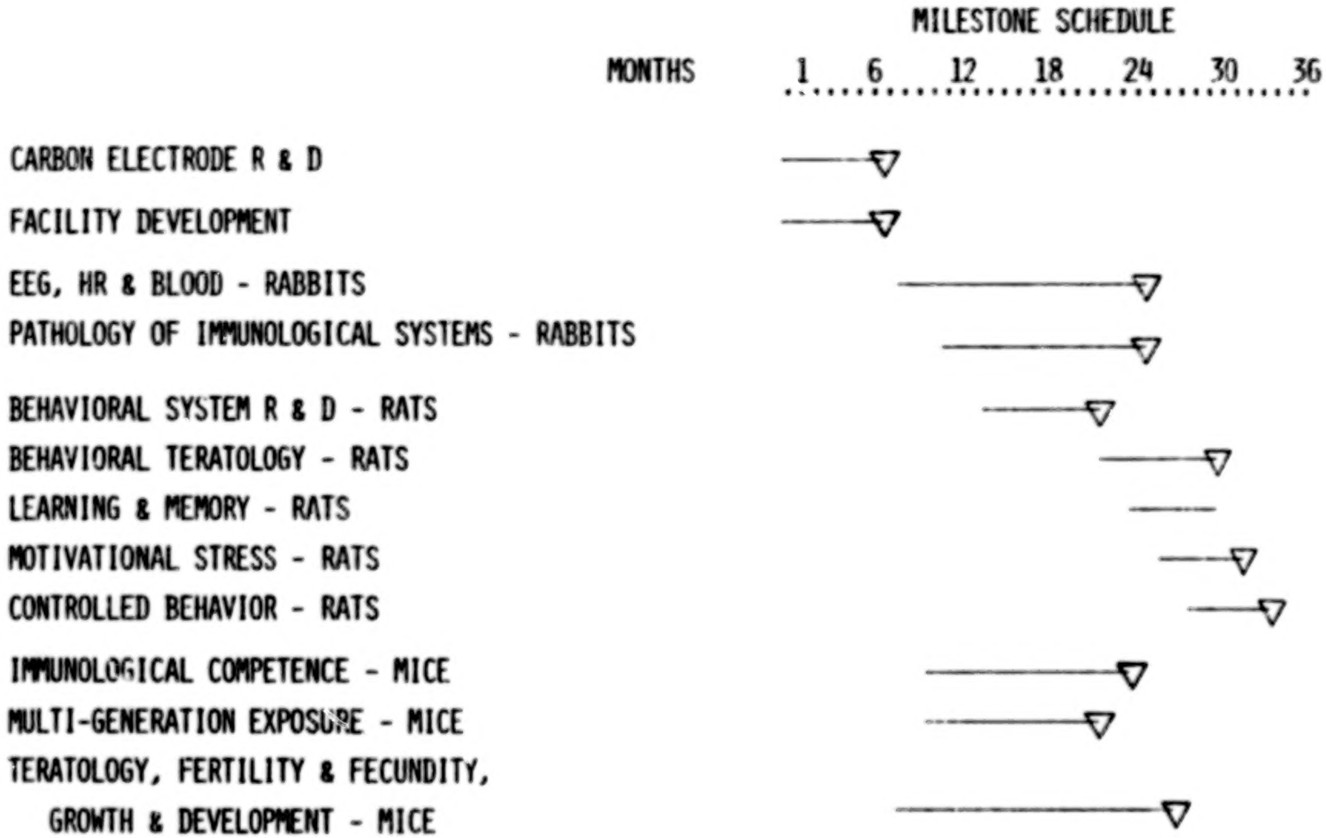
<u>Absorbed Dose - Birds and Reptiles. - Figure A-2.</u> - The most vulnerable of the fauna to the microwave beam of the SPS system, are the birds that might fly over the rectenna site. Being above the rectenna, they receive the full impace of the illumination and, in addition, may be subject to dose enhancement from reflection and modulation, due to the wing beats of birds in close proximity, as well as their own. It has been observed that biological effects are produced at a lower mean power density with pulsed microwave illumination than continuous wave (CW) illumination. In addition, many birds are of the correct dimensions to be in maximum resonance with the 2.45 GHz beam (Maximum absorption appears to be about a factor of 0.5 times the microwave wave length. The 2.45 GHz wave length is approximately twelve centimeters). A bird in flight

TABLE A-2

CHRONIC LOW DOSE

MICE, RATS & RABBITS

IN A CW 2.45 GHz ENVIRONMENT



$K BUDGETED $170K $149K $187K

is close to his thermal limits for existence, and if the absorbed energy from the microwave beams is not dissipated, it could lead to an intolerable increase in body temperature. Many reptiles are also within the dimensions and shape to make them an excellent absorber of microwaves, and in addition, these cold-blooded animals are heat seekers and may well be attracted to the microwave beam. Reptiles, such as the lizard, could climb onto the rectenna surfaces, and also be subject to high levels of microwave illumination. Both the birds and the reptiles, if attracted to these areas, could impact the systems, as well as having considerable ecological consequences.

In order to understand the consequences that microwaves might have on these animals, it becomes important to know what the specific absorbed radiation is, under the various conditions of exposure. For this reason, the dose absorption and mathematical modeling is necessary to understand and evaluate biological effects, in terms of Specific Absorbed Radiation (SAR). Such studies of dose modeling are also extrapolatable to larger animals such as man, if the correct factors for scaling can be developed. Such a scaling factor for this purpose, is the use of 9.8 GHz used with phantoms, or figurines, to enable extrapolation of absorbed doses to animals the size of man. Figure A-2 depicts the sequencing of facility development and experimentation to study the effects of 2.45 GHz on birds and reptiles, as well as working out the concepts of dose absorption modeling. The anticipated schedule of milestones is shown in Table A-3. Two facilities are developed in this effort - Facility 1 is common to all the experiments, and Facility 2 is required principally for the Dose Absorption Studies. Most microwave studies have been performed in anechoic chambers in such a way that a free space exposure, i.e., one not complicated by reflected or standing waves, is encountered. This simplifies observations but is not applicable to actual situations. In the first series of experiments depicted in Figure A-2, such exposures (protocol 1.1.2.0) will be compared with the absorbed energies where multi-animals are exposed, or where such a situation is duplicated using reflectors as described in protocol 1.1.4.0. Preliminary experiments in this area of investigation have shown an enhancement of energy absorption under such situations. Another situation which enhances the absorbed dose is the grounding of the animal and these experiments will be performed as described in 1.1.3.0. The information gathered will be applicable to the Bird Studies, investigating the effect that microwaves might have on the feeding characteristics, and the landing and take-off maneuvers using a wind tunnel, as described in protocol 3.1.4.0, and for those studies as described in protocol 3.4.2.0, which will investigate the attraction and avoidance of the birds

ABSORBED DOSE
BIRDS & REPTILES
IN A CW 2.45 GHz ENVIRONMENT

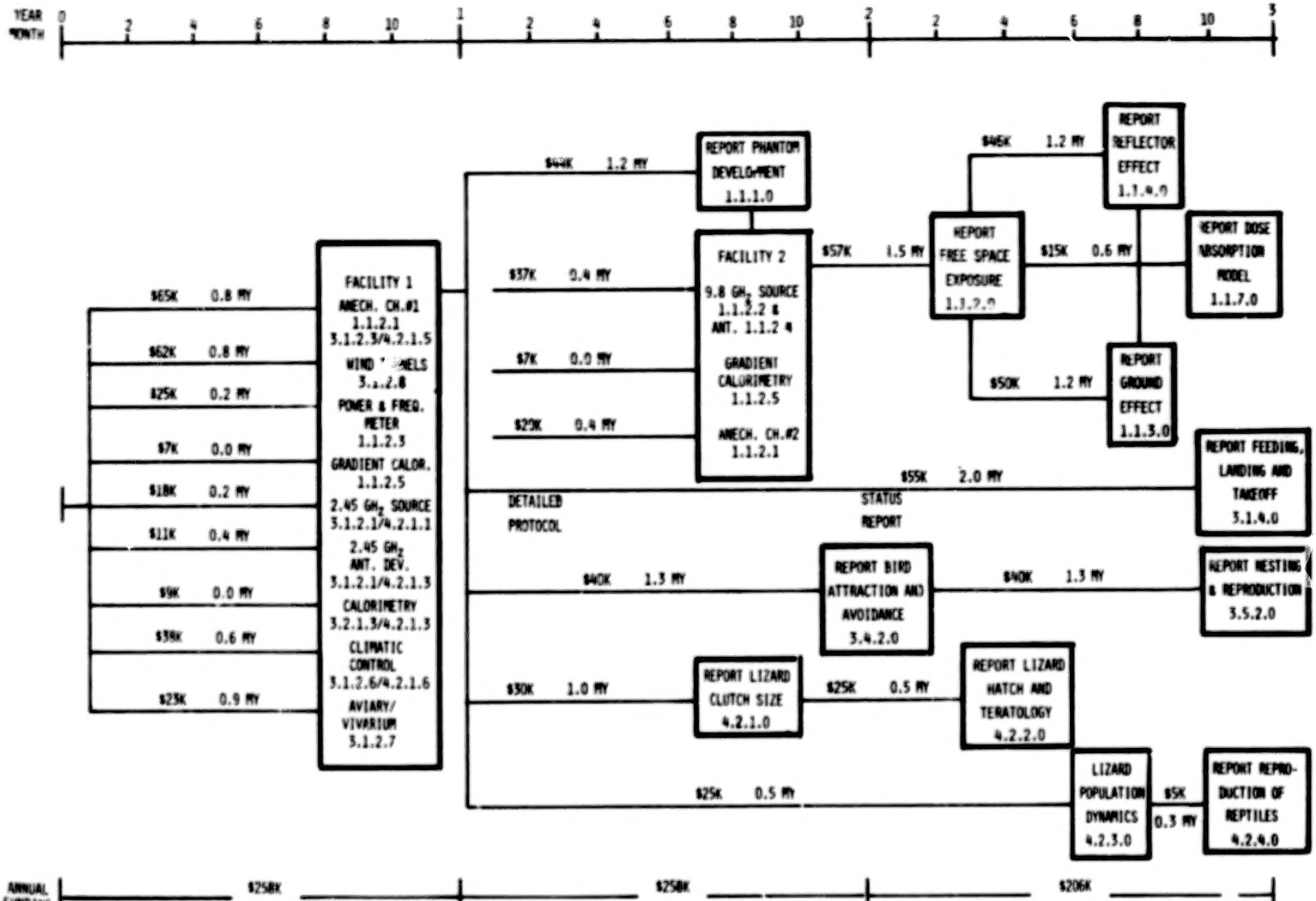


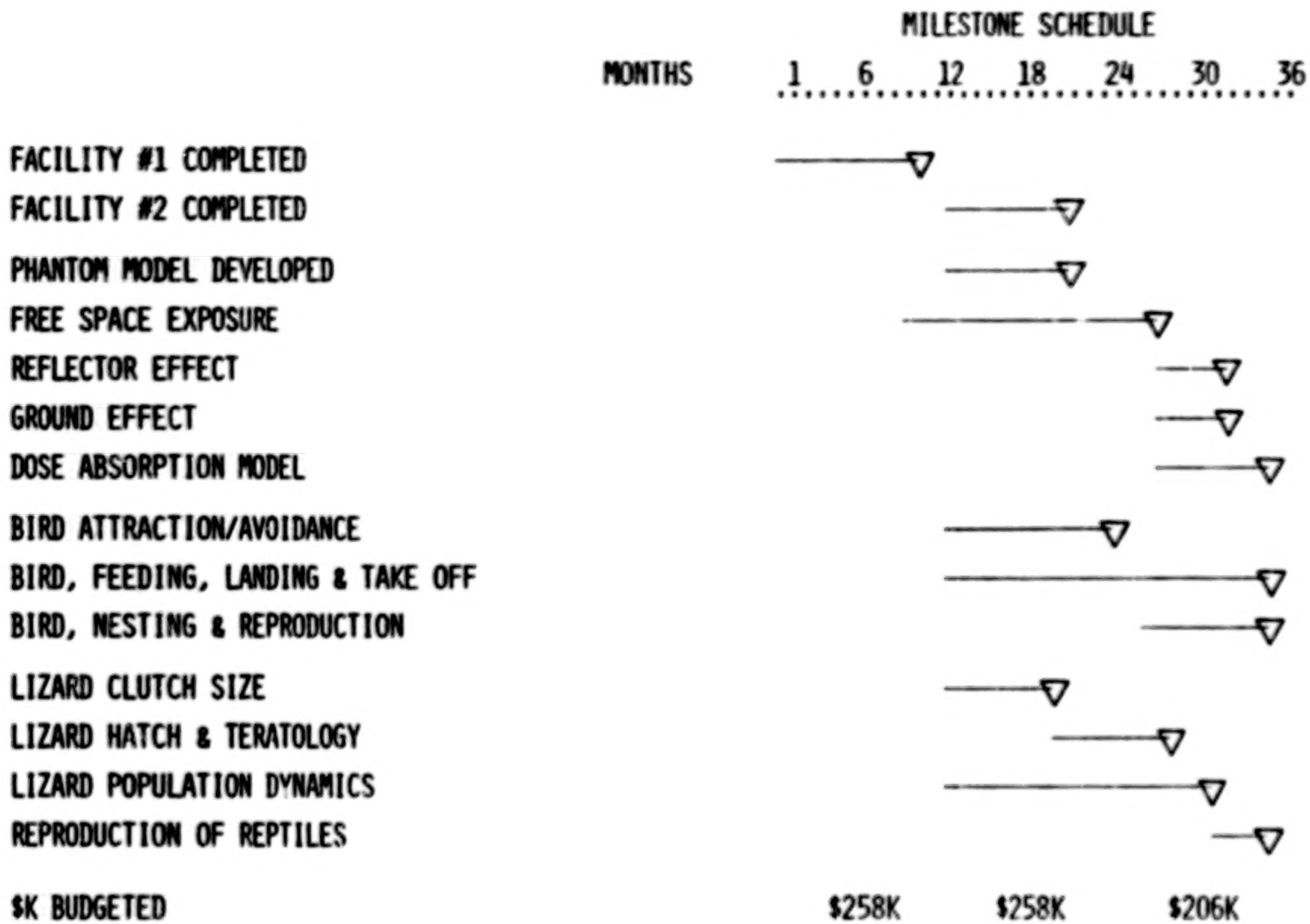
Figure A-2

TABLE A-3

ABSORBED DOSE

BIRDS & REPTILES

IN A CW 2.45 GHz ENVIRONMENT



to the microwave's source. Avoidance and attraction studies are important because of the implications to the migration of birds and how the SPS system might affect the principal flyways of many migrating species. Should the rectenna system provide a desirable area of protection and warmth for the birds, it can be anticipated that it will be an area for nesting and hence, illumination may affect the developine embryo and other aspects of reproduction. This is not only important to the ecology but it also could have system impacts by interfering with reception. These aspects are studied in 3.5.2.0.

Lizards are used as the representative reptile to study the effects on homeotherms (cold-blooded animals), the study of the clutch size as described in 4.2.1.0 protocol, and the effect that continuous illumination might have on the developing embryos are studied in 4.2.2.0. Concurrent with these studies, the total lizard population dynamics is studied, as described in 4.2.3.0, which will culminate in a report on the reproduction of the lizards, as an overall gross effect of the microwaves on this representative species.

One important question not considered in the abbreviated plan is the stimulus effect during flight which is proposed as question 3.3.0.0 in the ARC plan. The research objectives of those experiments is extremely important ecologically, as it has to do with the ability of the birds to navigate, as well as investigating the disruptive influences that an SPS transmission system might have on migratory flyways. The series of experiments that have been omitted are difficult to perform; they require long lead times and are beyond the funding limitations provided for this abbreviated plan. It is believed, however, that pertinent information pertaining to this problem will be gained through the experiments that are included, and labeled as attraction and avoidance under the protocol 3.4.2.0. Should those experiments indicate disruptive behavior and great sensitivity on the part of the birds to microwaves of low-power densities, an expansion of this investigative area would be appropriate under ecological support.

Invertebrates. - Figure A-3. - The flying insects, which may migrate into the SPS reception area and possibly be affected, could be ecologically important and also affect reception. Because the number of species within the Class *Insecta* number into the thousands, it is necessary to study a typical species in detail and then test how well it represents other species within the Class *Insecta*. The Honey Bee represents a typical insect in size and in many other characteristics and, because of its importance in pollinization and the manufacture of honey,

INVERTEBRATES
(BEE MODEL & REPRESENTATIVE CLASSES)
IN A CW 2.45 GHz ENVIRONMENT

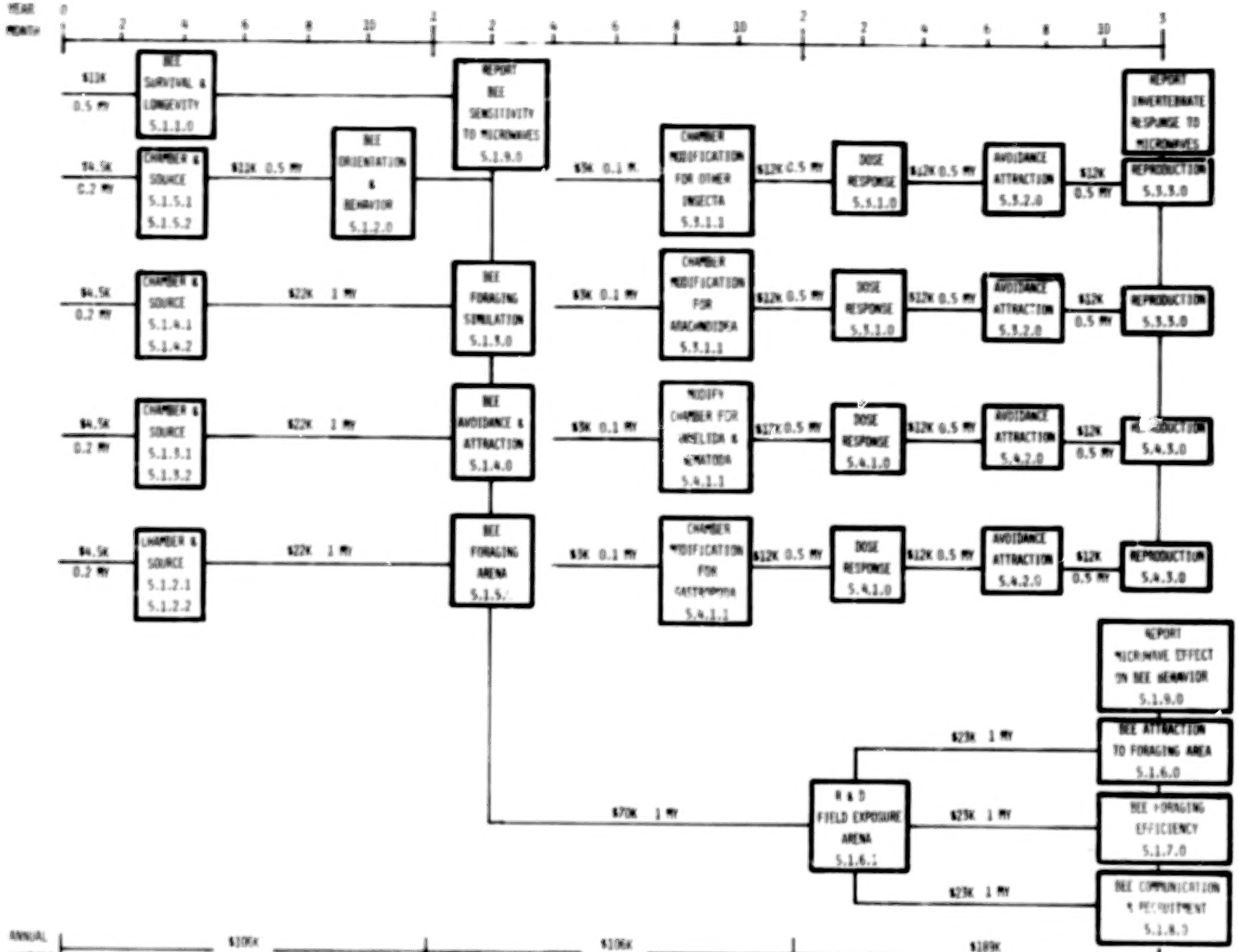


Figure A-3

a great deal is known about its behavior, as well as its physiology and biochemistry. Using the Bee as a model, microwave sensitivity is studied in 5.1.9.0 protocol, and mortality in 5.1.2.0; the effect on foraging capabilities in 5.1.3.0 and the avoidance and attraction studies--5.1.4.0, as well as 5.1.1.0, 5.1.2.0, and 5.1.5.0, will all provide information on the effects that microwaves might have on the behavioral aspects of insects at large. These studies are performed during the first half of the three year experimental period, within the confines of the laboratory. Experiments in the latter portion of the program are also concerned with the behavior, but are done in the field.

The facilities developed for the investigations on the Bee during the first half of the program, will be devoted to investigations on other invertebrates during the latter half of the program. The Bee model will be compared to other members of the *Insecta* Class, such as the ants, beetles, butterflies and grasshoppers, and to another Class within the *Arthropoda*, the *Arachnoidea*, which includes spider-like creatures, in protocol 5.3.1.1.

In addition to the *Arthropoda*, other invertebrates play important roles within the ecological system to maintain balance within the plant kingdom--these are the round-worms and earthworms classed as *Nemathelminthes* and *Annelida*. One of the chambers used for the bee investigations is modified for study of these creatures in 5.4.1.1. Another invertebrate playing a role within the ecological balance are the *Gastropoda* which are represented by snails and slugs. Each of these individual classes will be tested for their dose response, avoidance and attraction behavior, and for the effects that the microwaves may have on reproduction. Table A-4 gives the schedule of milestones and the yearly funding required for these studies.

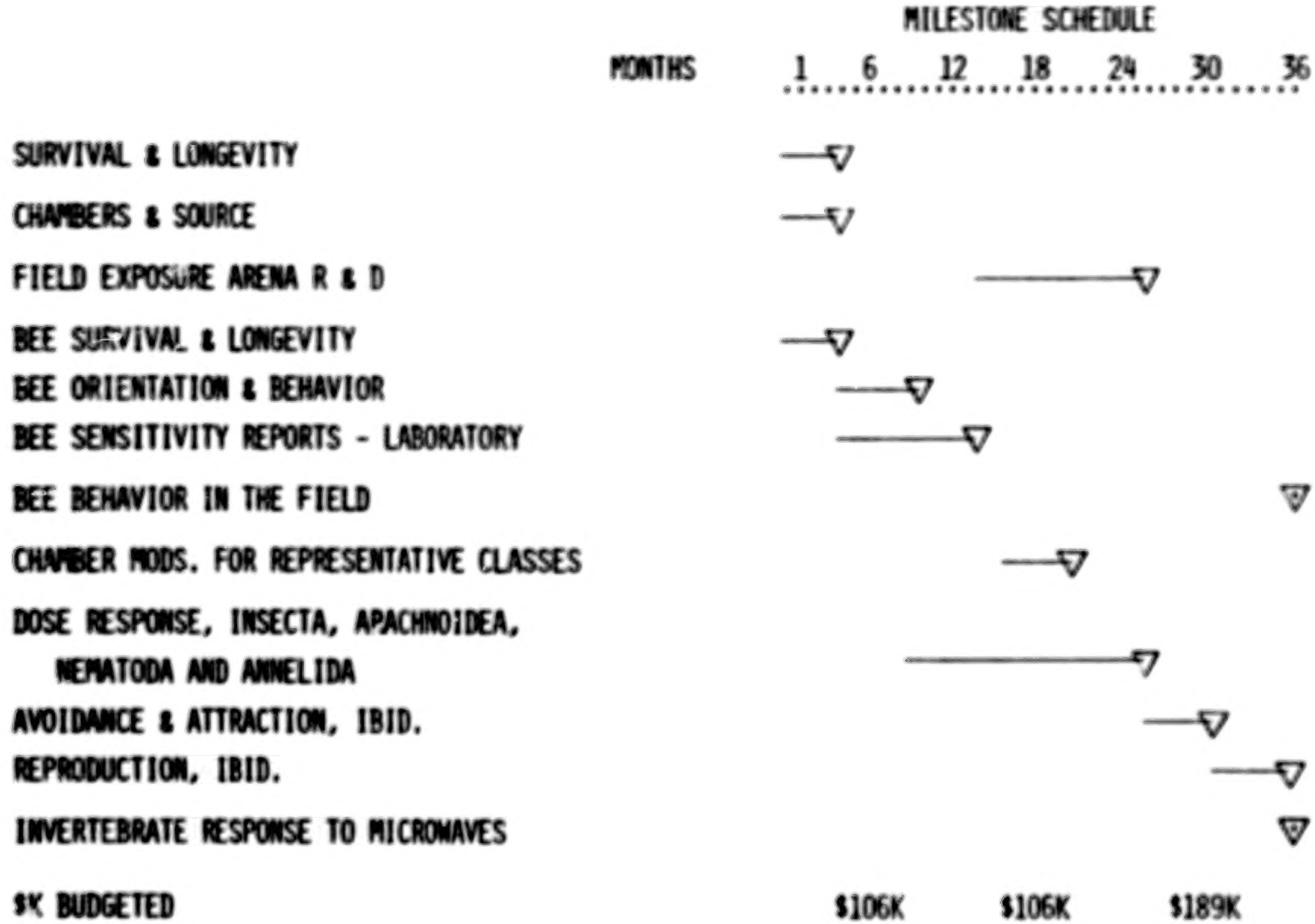
<u>Plants and Fungi. - Figure A-4.</u> - The plant life within the area of the rectenna site presents a unique problem for the biological effect studies. All of the animal species have means to combat thermal problems that might be encountered from microwave energy absorption by the means of a heat dissipating system, i.e., a circulation system of some kind, or there is a means of escape from the particular area into a cooler one. Change of position can also reduce the energy being absorbed in a case where the animal was well aligned with the E field, where maximum energy is absorbed. In the case of the plant, however, these possibilities do not exist, and what fluid shifts might occur, would be much less efficient

TABLE A-4

INVERTEBRATES

(BEE MODEL & REPRESENTATIVE CLASSES)

IN A CW 2.45 GHz ENVIRONMENT



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CROP PLANTS & FUNGI IN A CW 2.45 GHz ENVIRONMENT

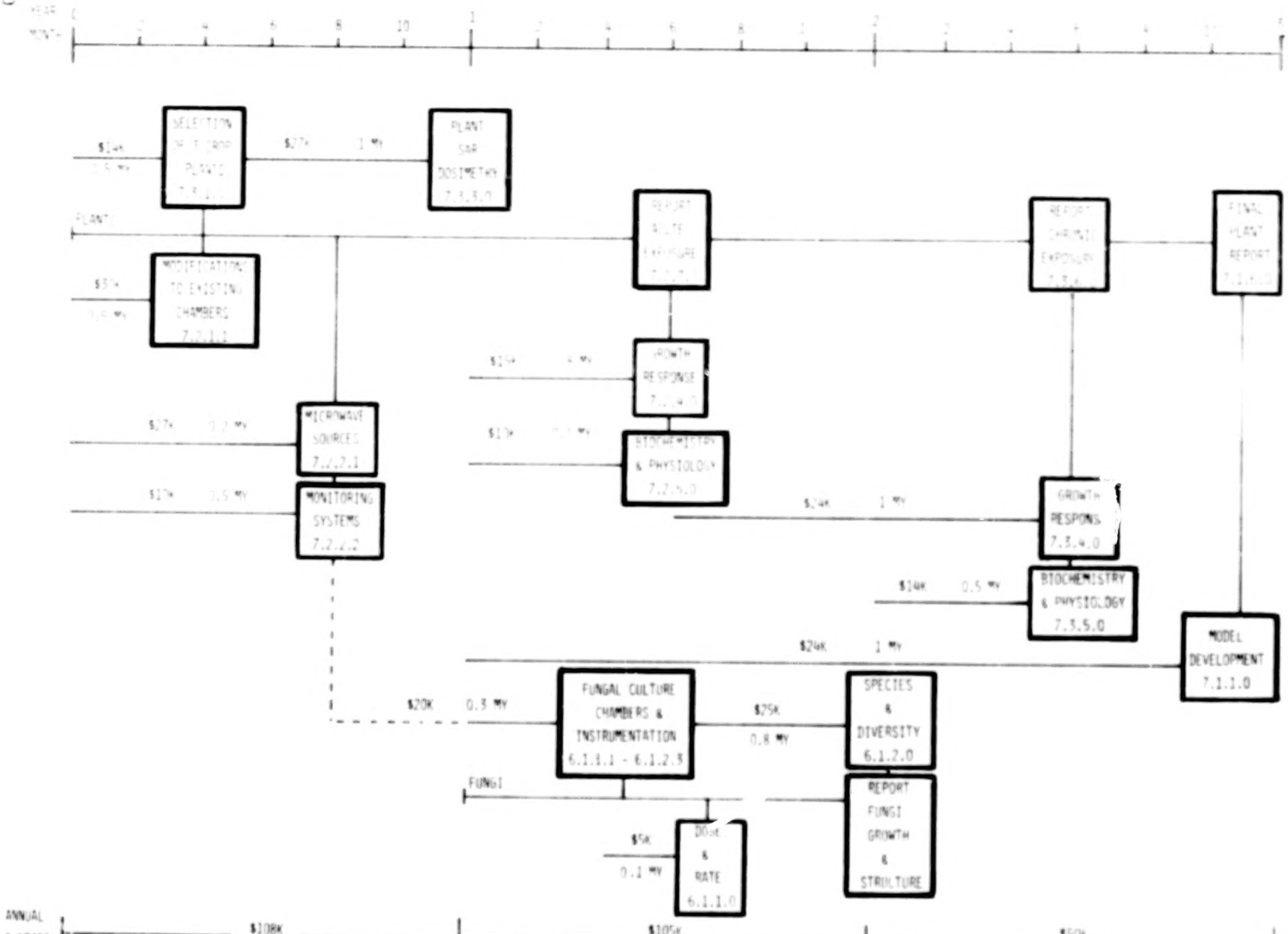


Figure A-4

for the purpose of removing internal heat. Those plants which grow erect will also be aligned with the plane of the E field which enhances dose energy absorption and at some point in growth, the height of the plant will be reached for maximum resonance. In addition, plants will be well grounded and will be receiving reflected energy. All of these factors, added up, could enhance the absorbed energy far above that which might be predicted.

It is anticipated that the energy levels of microwave illumination which will reach the ground around the periphery of the rectenna, and also through the rectenna nets, would be insufficient to produce significant effects upon the soil fungi, at the frequency of CW 2.45 GHz. However, it is important to confirm this hypothesis and to determine whether there is a possibility that accumulated energy effects will change the predominating species, or the diversity of species represented. These studies are described in protocols 6.1.1.0 and 6.1.2.0. Figure A-4 is summarized in Table A-5, as a schedule of milestones and annual funding required.

From the existing evidence, one would not anticipate direct effects from CW 2.45 GHz microwaves on fungal bodies. Investigations that report effects on yeast cells have mostly been done at much higher frequencies. There could be, however, significant changes in the ambient environment either on the ground, or on the surface of a plant, which would affect species balance and increase plant susceptibility to disease. For this reason, a limited amount of research on fungi has been included in Figure A-4 to insure that this factor is not overlooked.

If the concept were followed to place rectenna systems in existing agricultural tracts, rather than in a wild environment, or if a rectenna site and the restricting area around it are utilized for agriculture or tree farms, to reduce the land impact problem, this plant portion of research becomes a very important one. In the ARC research plan, it was assumed that wild plants, as well as crop plants, would be tested and specimen development accounted for a considerable amount of the cost and effort involved, because it is necessary to have genetically stable material to test. In this abbreviated plan, genetically stable material will be selected from varieties of crop plants that are liable to be encountered in site selection or site leasing. This will greatly reduce the effort involved and will insure that genetically stable species, with established cultural requirements, are being tested. The procedures, however, are still similar to those outlined in protocol 7.3.1.0. Modifications in any existing chambers will be necessary to provide the correct environment and cultural require-

TABLE A-5

CROP PLANTS & FUNGI

IN A CW 2.45 GHz ENVIRONMENT

MILESTONE SCHEDULE

MONTHS 1 6 12 18 24 30 36

CHAMBER MODIFICATION

MICROWAVE SYSTEMS

SAR DOSIMETRY

PLANT SELECTION

ACUTE-GROWTH, BIOCHEM. & PHYSIOL. PLANTS

CHRONIC-GROWTH, BIOCHEM. & PHYSIOL. PLANTS

MODEL DEVELOPMENT, PLANTS

FINAL REPORT, PLANTS

FUNGAL FACILITY

FUNGI DOSE & RATE RESPONSE

FUNGI SPECIES & DIVERSITY

FUNGI GROWTH & STRUCTURE REPORT

$K BUDGETED $108K $105K $51K

requirements for the selected material. As mentioned previously, the energy absorption of the growing plant could be quite a unique dosimetry problem and influenced by many factors. The specific absorbed dose must be determined in relation to the incident microwave beam and this will be performed under protocol 7.3.3.0. Acute exposures of the plant material are necessitated by the time factor and limitations in funding. In the SPS operational system, such exposures would not occur, but the problems concerning changes in absorbed energy with the various heights of the plant can best be investigated by growing specimens to various heights under optimal conditions but without microwave illumination. At various times within the plant growth period, it can then be exposed for periods of several days at low doses. In this way, the sensitivity of the plants to the illumination at various times in the life period of the plant can be investigated. These experiments are described in 7.2.4.0 and 7.2.5.0. It will also be necessary to determine if accumulated effects occur when the plant is raised from a seedling to maturity in the microwave environment. These studies are labeled the chronic exposures and are covered under protocols 7.3.4.0 and 7.3.5.0.

Because it is anticipated that effects will be of a thermal type and considerable data is available about the thermal responses of plants, it should be possible to develop a predictive model and substantiate it, using the information gained from the studies on specific absorbed radiation, acute exposures, and chronic exposures being performed over the three year period.

Programmatic Coordination, Reporting, and Dosimetry Workshop Arrangements. - Figure A-5. - Most of the tasks shown in Figure A-5 do not appear in the original ARC research plan. During the development of that plan, it was found that the programmatic approach to provide the visibility desired by NASA management, into the research programs being conducted was most easily accomplished by the integrating contractor obtaining the required information, and developing the charts. This allowed the researchers more time for their tasks and provided reviewers with a more consistent approach to the schedules, milestones and expenditures. For this reason, an interface has been proposed which would act as a means to provide the DOE and NASA management with the information their management requires, in the forms used by the respective offices for that purpose. Immediatley after the award of such a contract, the interface contractor would develop necessary formats for reporting milestones, funding schedules, etc., in the manner described by the cognizant office. The tasks are

PROGRAMMATIC COORDINATION & REPORTING TO INTERFACE BETWEEN UNIVERSITY LABORATORIES AND DOE / NASA MANAGEMENT

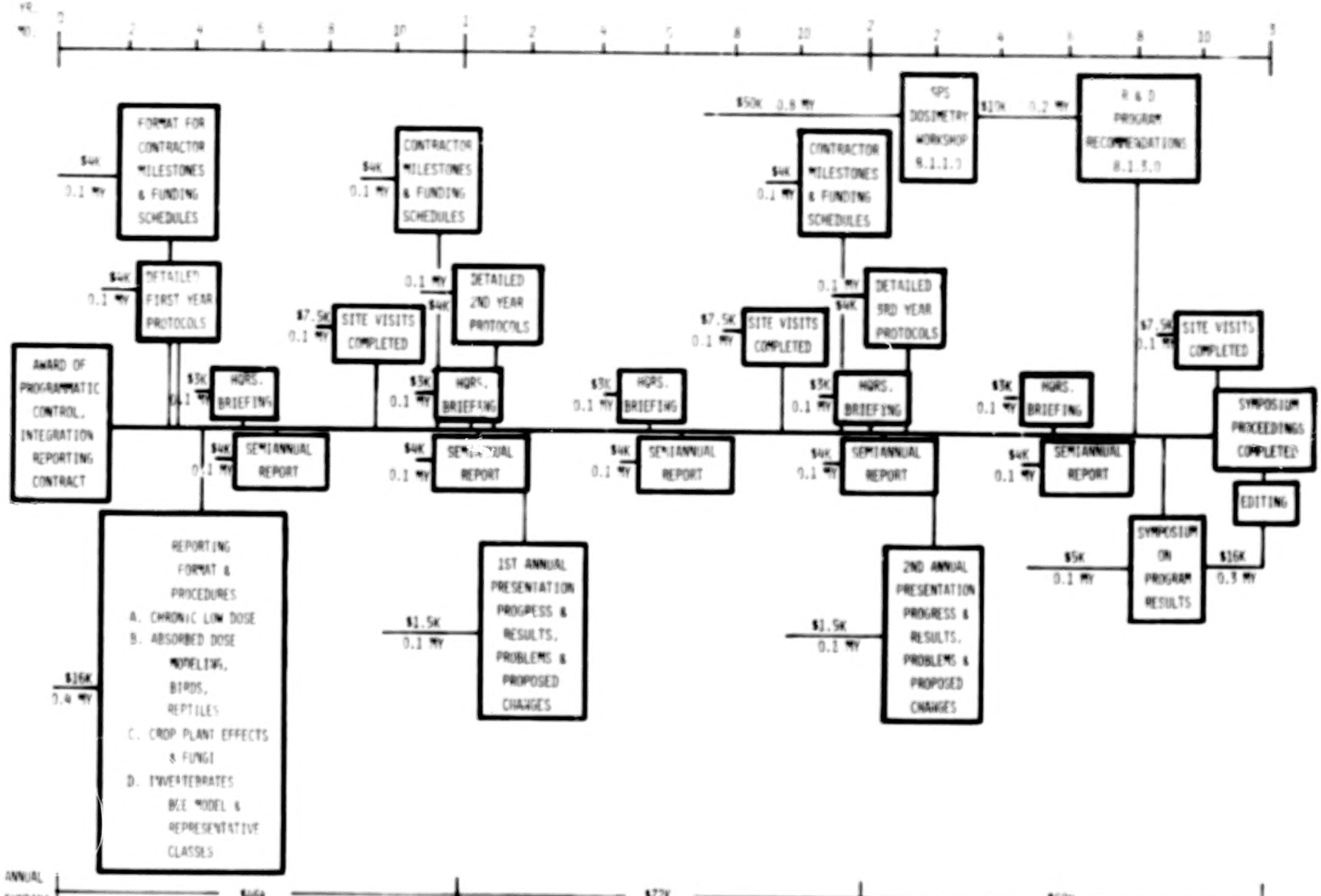


Figure A-5

detailed in Figure A-5, and summarized as milestones in Table A-6.

Following award of the various contracts, each investigator would develop a series of detailed protocols for his laboratory experiments, which would be a great deal more specific than those described in the proposals or the contract. It is from these detailed protocols that exact milestone dates and funding obligations can be derived. The preparation of each of these detailed protocols would be repeated at the beginning of each contract year. With this information available, it is possible for the interface contractor to prepare the formats, and set the minimum procedures for reporting by each investigator to provide management with full visibility, without imposing a heavy paper work burden upon the resea chers. It is proposed that the interface contractor provide the headquarters agency with a briefing each six months on an informal basis, about the status of progress, suggested changes and action items. The text of this briefing will be more formally presented in a written report.

Three site visits are planned during the program period when the interface contractor would accompany a management representative to inspect facilities, the manner in which experimentation is being conducted, and to become more familiar with any problems that exist.

At the end of the first and the second years of the research program, a closed meeting is held for all of the principal investigators to attend and present their progress, to discuss their problems and to negotiate any proposed changes from the original program that they might deem necessary. These meetings would also allow discussions between investigators concerning problems in microwave exposure techniques, dosimetry, etc. At the completion of the three years research program, an open symposium will be conducted on the results derived during the three years research, and the proceedings of that symposium will be prepared as a formal report.

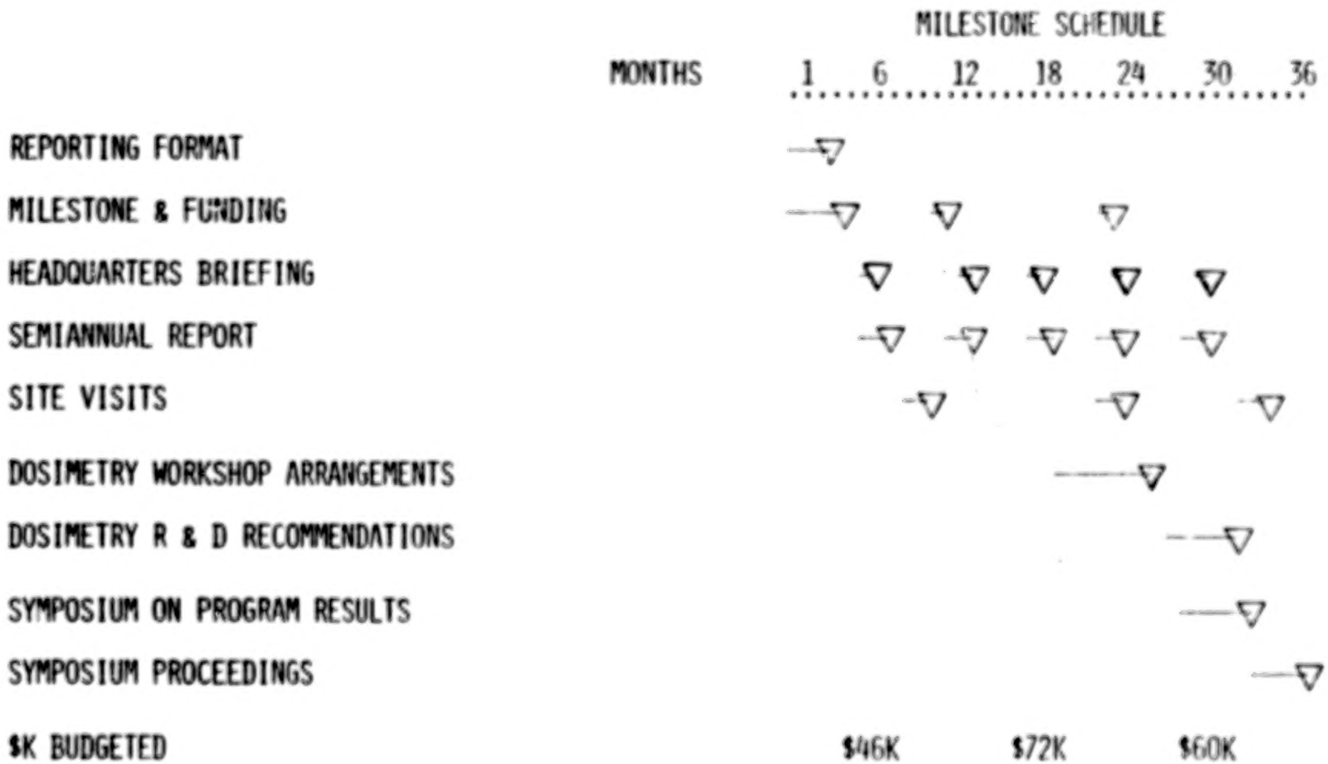
An additional task is shown in Figure A-5 which is incorporated into the interface contract, as it is non-technical, and is to provide the arragnements necessary to conduct an SPS dosimetry workshop. Personal and subject dosimetry is extremely rudimentary at this time, and none of the techniques now existing, satisfy the requirements of the SPS system. Dosimetry development, both conceptual and for hardware, has an extremely long lead time and is important to initiate as soon as possible. The objective of the dosimetry workshop is to bring together experts in this particular aspect of microwave

TABLE A-6

PROGRAMMATIC COORDINATION & REPORTING

TO INTERFACE BETWEEN UNIVERSITY LABORATORIES

AND DOE / NASA MANAGEMENT



technology, to explore and suggest possibilities for developing hardware items, to be used specifically for the frequency and energy levels associated with the problems within the SPS rectenna site. Following the dosimetry workshop, the proceedings will be documented and the program recommendations prepared as a report.

Conclusion. - It is believed that a meaningful and pragmatic research program can be completed in the three year period and stay within the $2,100,000.00 allotted. It is a way to get started and to discover if there are critical problems not now anticipated, either in the ecological acceptance, or as an impact on system design. Should such problems be uncovered, the funding of additional experimentation would then be required.

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16. Abstract

A programmatic research plan for a three year study is presented to generate knowledge on effects of the continuous wave 2.45 GHz microwave power transmission of the Solar Power Satellite might have on biological and ecological elements, within and around the rectenna receiving site.

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